Appendix E2 – Restoration Plans and TMDLs (Restoration Plans)

Impervious Area Assessment

February 14, 2017

Joseph J. Siemek, P.E.
Director of Public Works, Harford County
212 South Bond Street, 3rd Floor
Bel Air, MD 21014

Dear Mr. Siemek:

The Maryland Department of the Environment (MDE) acknowledges receipt of Harford County's revised impervious area assessment. Upon review of the revised analysis, some of the information previously requested by MDE remains incomplete. Based on the information that could be verified, MDE has determined that the County's impervious area baseline is 11,094 acres. Please be aware that the County may submit a revised baseline as part of the fourth year permit renewal application.

Harford County's permit requires the restoration of 20% of previously developed land that has little or no stormwater controls as described in Chesapeake Bay watershed implementation plans. Based on the County's impervious area baseline of 11,094 acres, the County's restoration requirement this permit term is 2,218 acres.

Incomplete information will need to be addressed before treated impervious acres can be accounted for in a revised baseline. MDE's full review can be found in the Attachment. Major comments include:

- Data required to receive impervious area credit are incomplete. Missing data include inspection dates and construction completion dates.

- Dry extended detention structures do not meet the performance criteria found in the 2000 Maryland Stormwater Design Manual and, therefore, cannot be used to deduct acres from the baseline.

- A field investigation is required to validate the desktop analysis used to estimate impervious area disconnects.

MDE would like to commend Harford County for its efforts to implement an effective stormwater management program. Because this work is essential in our mutual quest for restoring urban streams and the Chesapeake Bay, I would like to thank you and your staff for your continued efforts. If you have any questions regarding this review, please contact me at 410-537-3545 or Ms. Christina Lyerly at 410-537-3546 or christina.lyerly@maryland.gov.

Sincerely,

Raymond P. Bahr
Program Review Division Chief
Sediment, Stormwater, and Dam Safety Program

cc: Ms. Christine Buckley, Harford County

Attachment

Attachment
Maryland Department of the Environment's Review of Harford County's Revised Impervious Area Assessment Report FY2016

In Harford County's 2015 Impervious Area Assessment, the County proposed an impervious area restoration baseline of 9,413 acres. Maryland Department of the Environment (MDE) requested additional information prior to approval. On August 1, 2016, the County submitted a revised impervious area baseline of 10,345 acres. Upon review of the revised analysis, some of the information previously requested by MDE remains incomplete. Therefore, MDE has determined that the County's impervious area baseline is 11,094 acres, based on the information that could be verified. A summary of calculations can be found in the below tables. Based on the approved baseline, the County's restoration requirement for this permit term is 2,218 acres.

Approved:

12,076 acres	Total impervious area in Harford County
-941 acres	Deduction for agricultural properties
-41 acres	Deduction for 12SR NPDES properties
11,094 acres	**Approved Baseline**

Not Approved:

331 acres	Extended Detention Structure, Dry (EDSD) stormwater management facilities do not meet the performance criteria found in the 2000 Maryland Stormwater Design Manual
187 acres	Data are incomplete for pre-2002 stormwater management facilities
79 acres	Field investigation is required to receive credit for impervious area disconnects
106 acres	Data are incomplete for watershed restoration best management practices (BMPs) completed through 2009
87 acres	Data are incomplete for watershed restoration BMPs completed after 2009

The County may submit a revised baseline as part of the fourth year permit renewal application. Incomplete information, including inspection and construction completion dates, will need to be addressed before treated acres can be accounted for in a revised baseline. Detailed responses are provided below to clarify the additional information that remains outstanding.

1. The County requested credit for 246 pre-2002 stormwater management facilities that provided water quality treatment for ½ inch of rainfall. However, the County had not identified those facilities and, therefore, did not provide sufficient information for MDE to verify this deduction. In its revised baseline assessment, the County reviewed these facilities and removed 21 BMPs due to duplicate data or missing facility types. The County decreased its impervious area restoration credit from 677 to 519 acres. MDE has the following comments on the remaining 225 facilities:

    a. The County provided a list of the pre-2002 facilities in Appendix A. Five facility types were included, four of which would qualify for treatment of ½ inch of rainfall. Per the 2014 *Accounting for Wasteload Allocations and Impervious Acres Treated* guidance document (2014 guidance), EDSD facilities do not meet the performance criteria found in the 2000 Maryland Stormwater Design Manual, but they are great opportunities for County restoration projects. The 162 EDSD facilities, representing 331 impervious acres, must be added to the baseline. The total treatment credit that would be received for the remaining 63 pre-2002 facilities is 187 acres.

b. The County's urban BMP database is missing key information that is required to receive water quality treatment credit, including all inspection dates. MDE acknowledges the County's efforts to transition its data to the new MS4 geodatabase. However, inspection information is required to verify that these facilities have been maintained and are functioning. A small number of facilities are missing construction completion dates. Until the County can provide complete data for the above-mentioned pre-2002 facilities, the 187 impervious acres treated will remain in the County's baseline.

2. The County's desktop methodology for identifying impervious surface disconnects is acceptable. The County reduced its deduction from 361 to 79 acres. However, as stated in MDE's 2014 guidance, additional field investigation on a representative sub-set of these properties is necessary to validate the desktop analysis and to document the types and extent of Environmental Site Design practices. The survey and GIS analysis shall be submitted to MDE for approval. The 79 impervious acres treated will remain in the County's baseline until a field investigation is approved and conducted.

3. The County deducted from its baseline watershed restoration completed through the expiration of its prior permit (2009). MDE approved this time frame. The County reported these BMPs in a Capital Improvement Project database. However, this database was missing data required to receive credit. Construction completion dates are allowable for restoration practices. However, last inspection dates are required to verify that these facilities have been maintained and are functioning. Until those data are submitted, the 106 impervious acres treated will remain in the County's baseline.

4. To date, the County reported restoring 87 acres, representing 4% of its 2,218 impervious acres to be restored within this permit term. The County applied credit for restoration projects completed between the expiration of the last permit (2009) through the present toward its 20% restoration requirement. MDE accepted this time frame. However, complete data, including inspection dates, are required to receive impervious acre credit for restoration. These acres can be applied to the County's restoration once the data are complete.

5. The County's methodologies for accounting for sidewalks and identifying agricultural properties are acceptable.

6. The County verified that the 25% impervious area assumption for residential lots was conservative. The County's methodology is acceptable.

August 1, 2016

Mr. Raymond Bahr
Water Management Administration
Maryland Department of the Environment
1800 Washington Blvd.
Baltimore, Maryland 21230

Dear Mr. Bahr:

Harford County is submitting the enclosed response to MDE's review of the County Impervious Surface Assessment in accordance with your letter dated April 6, 2016.

As noted within the County's response, MDE's request for additional analysis for exclusions of impervious surface can be labor and cost intensive. Harford County continues to contend that many of these areas lay outside of the County's MS4 Permit Area. Harford County has addressed MDE's review by allocating a conservative level of effort based on the pending outcome of the County's appeal of its MS4 permit.

The County expressly reserves its rights to reduce the acreage identified in the Assessment to the minimum acreage the permit can legally require. In addition, the County expressly reserves the right to make future refinements to the Assessment based upon new or additional information consistent with an adaptive management approach.

Should you have any questions, or wish to discuss this submittal, please feel free to contact Christine Buckley at (410) 638-3217 extension 1176, or me at (410) 638-3285.

Sincerely yours,

Joseph J. Siemek, P.E.
Acting Director of Public Works

JS/cmb
Enclosures

cc:

The Honorable Barry Glassman	J. Stratmeyer	C. Lyerly (MDE)
B. Boniface	M. Rist	
M. Hartka	C. Buckley	
S. Kearby	B. Appell	

Scope of Work for Identification of Existing Grass Swales

ISO 9001:2000 CERTIFIED
KCI TECHNOLOGIES
ENGINEERS • PLANNERS • SCIENTISTS • CONSTRUCTION MANAGERS
936 Ridgebrook Road • Sparks, MD 21152 • Phone 410-316-7800 • Fax 410-316-7885

April 21, 2017

Ms. Christine Buckley
Harford County Department of Public Works
Watershed Protection & Restoration
212 S. Bond Street
Bel Air, MD 21014
(410) 638-3545 ext.1176

Contract No.:	16-153
Contract Name:	On-Call Environmental Design and Assessment
Project No:	171700458
Task Number:	01
Task Name:	Identification of Existing Grass Swales for Harford County
Task Manager:	Christine Buckley

Dear Ms. Buckley:

At the request of Ms. Christine Buckley, KCI Technologies, Inc. (KCI) is pleased to submit the attached scope and price proposal to complete Task 01 - Identification of Existing Grass Swales for Harford County under Contract No. 16-153. The budget for Task 01 services totals $109,028.00. This proposal will cover the completion of the Desktop Analysis and engineer review for 3,000 potential 2A swales in prioritized areas of the County. KCI anticipates completion of the task within approximately 4 months after notice to proceed is granted.

We are available to discuss any details of this proposal with you at your convenience. Thank you for your consideration, and we look forward to performing these services for the Harford County.

Sincerely,

Kerry Rexroad, PE
Vice President, Water Resources

cc: Ms. Christine Buckley / Harford County DPW
Mr. James Tomlinson, PE / Primary Liaison for KCI
Mr. Douglas V. Goldsmith / Vice President for KCI

SCOPE OF WORK

As an element of Harford County's Chesapeake Bay Restoration Plan, Harford County is identifying the locations and assessing the effectiveness of grass swales. In order for an area to be classified a "grass swale," it must meet several established criteria as defined by Maryland Department of the Environment (MDE).

The following proposal, submitted by KCI Technologies, Inc. (KCI) describes our suggested approach to perform desktop analysis of existing open section drainage in order to properly identify those that meet the grass swale requirements from MDE within Harford County's right of way countywide. Establishing a current and correct list of grass swales will allow Harford County to collect and document the baseline credit reduction for the impervious surface treatment provided by the grass swales, ultimately reducing the County's 20% impervious restoration requirement in the NPDES permit.

To perform the desktop analysis to identify grass swales within Harford County ROW, KCI will reference the Existing Water Quality Grass Swale Identification Protocol approved by MDE on May 18, 2016, and established by Maryland State Highway Administration and KCI. This scope of work will involve performing the desktop analysis to review up to 3,000 potential 2A grass swales that are to be measured and verified in the field. A 2A swale is defined by meeting MDE's criteria for an M-8 Best Management Practice. Field verification and final full grass swale analysis will not be included in this scope of work. The following are the primary services to be provided under this scope of work:

- Complete the desktop analysis to create flowlines and categorize swales in preparation for field measurements and verification.
- Conduct water resources review in the desktop environment up to 3,000 potential 2A swales developed from the desktop analysis to update, clean, and perform quality control of the desktop analysis results.
- This approach will provide Harford County with up to 3,000 potential 2A grass swales in prioritized areas that are ready for field measurement and post processing to confirm the function as a water quality swale and account for the treatment in the County's impervious surface baseline accounting. It assumed that less than 3,000 *final* 2A swales may be identified after the engineer reviews up to 3,000 potential 2A swales.

KCI will provide a scope and cost for the field verification and post processing effort for the prioritized swales upon completion of this task, at the request of Harford County.

<u>TASK 1: PROJECT INITIATION / MEETINGS</u>

Upon receipt of notice to proceed, KCI will meet with Harford County to discuss the project and kick off the work effort. Discussion topics during this initial meeting will include:

- Materials and available information to be supplied by Harford County.
- Communications plan.
- Project schedule.
- Deliverables.
- Grass swale protocols as established by MDE.
- Official source of the DEM layer, contours, impervious surfaces, and other required GIS data to ensure availability and accessibility of the database.
- Submission procedures / requirements.

KCI anticipates having up to two (2) progress meetings with Harford County to discuss the progress of the project. The purpose of the progress meeting is to discuss the project status, budget, schedule, and hindrances. The progress meetings may be online or in person meetings, at the County's preference. KCI will prepare agendas to outline the topics for discussion and will identify stakeholders required to be present. Following each meeting, the project manager will complete and distribute meeting minutes to all meeting attendees. The minutes will be distributed within five (5) business days after the progress meeting.

KCI will also deliver project updates in the form of monthly progress reports, which will indicate the project completion percentage and dollars remaining as of the date of submission. At a minimum, progress reports will detail the following:

- Number of potential swales per category identified from the desktop analysis.
- Number of 2A swales upon completion of engineer review.

Deliverables

- *Kickoff agenda and meeting minutes*
- *Progress meeting agenda and meeting minutes*

- *Monthly progress reports*

TASK 2: DESKTOP ANALYSIS

KCI will utilize the MDE-approved standard operating procedures and lessons learned during past swale tasks with SHA to complete the desktop analysis tasks within the County-owned ROW. The following are the primary tasks to be performed under Task 2:

- Generate flowlines utilizing GIS tools and the DEM layer.
- Auto-generate flowline longitudinal slopes and side slopes values using GIS tools and extensions.
- Manually identify the bottom material of the flowlines using aerial imagery and Google StreetView (when available).
- Categorize grass swales based on swale parameter values; merge like flowlines based on parameter values.

GIS Data Collection & Project Setup

KCI will provide a list of GIS source data required and will coordinate with Harford County to receive the most current versions. The source data includes but is not limited to County DEM layer, LiDAR data, roadway centerline, 2-ft elevation contours, curb layer, county storm drain and BMP layers, ROW layer, impervious layer, and aerial imagery. It is assumed that Harford County will be using the impervious layer from the baseline year for Harford County. KCI will consolidate the GIS data to ensure that the team has the full data sets required to complete the desktop analysis. KCI will create a standard symbology set and ArcGIS map project that will be used throughout the project by the team.

KCI will create a grid index to split the county into tiles. The grid index will be used for status tracking and planning the desktop compilation and water resource engineer quality control. KCI will process the LiDAR datasets to generate a seamless 10ft x 10ft DEM (Digital Elevation Model) grid database using the WISE Terrain Analyst (WTA) or the equivalent ArcGIS 10.0 extension for ArcMap. The resultant DEM will be used to develop the initial flowlines and to auto-populate swale geometry features.

Desktop Analysis Workflow

KCI will discuss with the County to determine if there are specific index grids or corridors that have priority. The prioritized corridors would be those where shoulder and/or median ditches may exist or roads where curb does not exist. Prioritized locations will allow KCI to focus on areas that might result in the most potential 2A swales for analysis and engineer review. The prioritized locations will ensure that KCI is efficient in the identification of the 2A swales and can maximize the work effort. KCI will begin the processing for the index grids / locations that show the more dense opportunity to identify potential 2A swales. Upon completion of pilot grids KCI and Harford County will evaluate the success of identifying 2A swales and may modify the analysis as required.

The goal of the desktop analysis is to calculate the grass swale criteria for each parameter outlined in the operating procedures and assign a category based on the parameter values. The values for each flowline parameter will be recorded in a line feature class table. KCI will utilize the ArcGIS tools and the DEM layer to generate potential flowlines for each index grid. The resultant flowlines will be split into smaller segments for criteria analysis as outlined in the operating procedures. KCI GIS Analysis will remove flowlines that are outside of a designated buffer to Harford County ROW, flowlines that are within impervious areas, and those flowlines that are not ditch / swales based on aerial imagery and StreetView. Flowline geometry will be updated as needed to cut, combine, and lengthen flowlines. KCI will also remove flowlines that are parallel to curbs, if a curb GIS layer is available. Otherwise curbs will be identified through StreetView imagery.

KCI will auto-calculate using GIS tools and record in the flowline feature class the longitudinal and side slopes for each flowline segment. KCI will manually review each flowline to identify and record the bottom material of the flowline using aerial imagery and StreetView. The slope value and bottom material will be recorded in the flowline feature class. KCI will dissolve flowlines that are adjacent to each other based on similar longitudinal slope, side slope, and bottom material values.

KCI will assign a Category (2A, 2B, 3A, 3B, etc.) for each dissolved flowline based on longitudinal slope, side slopes, and bottom material values. A unique identifier for each potential swale will be created. Upon completion of Task 2, the team will have developed a line feature class of potential swales with geometry and attribution including longitudinal slope, side slope, bottom material, and a unique identifier.

Deliverables

- *Conditioned DEM layer used to generate flowlines and swale parameter values*
- *Categorized flowline line feature class attributed with criteria values.*

TASK 3: POTENTIAL SWALE QUALITY CONTROL

The goal of Task 3 is to ensure that the potential 2A swales categorized in Task 2 have proper limits and category. Water Resource Engineers will perform quality control on the desktop analysis results to ensure the quality of potential 2A swales. The following are the primary tasks to be performed under Task 3:

- Perform Water Resources Engineer QC of swale lines for up to 3,000 potential 2A grass swales.
- Compile a list of up to 3,000 potential 2A swales that would require field verification and measurements.

KCI will identify the 3,000 potential swales for review by selecting index grids and areas of the County that have the majority \ clusters of potential 2A swales based on the desktop analysis results. If more than 3,000 potential 2A swales exist in the County that require engineer review, KCI and the County will discuss options.

KCI engineers will utilize the elevation contours, aerial imagery, and Google StreetView while reviewing the swales. Using design experience and engineer's discretion KCI will verify and update the geometry and swale category as needed to identify valid 2A swales. The updates may include extending or shortening swale limits and / or updating the category of the potential swale. KCI will provide a list of the swales identified as potential 2A swales for field verification.

Deliverables

- ***Updated categorized flowline line feature class attributed with criteria values.***
- ***Line feature class of up to 3,000 potential 2A swales that would require field verification***

ASSUMPTIONS

The following assumptions have been made in the development of this proposal:

- Project execution will follow the Existing Water Quality Grass Swale Identification Protocol approved by MDE on May 18, 2016, protocol appendices, and lessons learned during previous swale task.
- The resultant grass channels in compliance with the protocol will meet or exceed the criteria of a MDE M-8 grass channel.
- Harford County, in conjunction with KCI, will provide the base LiDAR / DEM and GIS data necessary to complete the project.
- All GIS submittals shall be ArcGIS 10 compatible and based on Maryland State Plane Projection.
- An H&H Engineer will be responsible for the final deliverables and category values assigned to the potential grass swales
- It assumed that less than 3,000 *final* 2A swales may be identified after the engineer reviews up to 3,000 potential 2A swales.
- Drainage area delineation will not be included in this scope of work. KCI has learned from past tasks using the grass swale standard operating procedures that drainage areas should only be delineated after field verification. KCI has learned that time is wasted delineating drainage areas for swales that do not meet the 2A criteria after Desktop Analysis, and that field verification de-categorizes potential 2A swales. KCI has found that it is more time and cost effective to delineate drainage areas after field verification, and that drainage areas are more accurate when delineated during fieldwork.
- Field measurements / verification are not included in this scope of work.
- The resultant output of up to 3,000 potential 2A swales identified through this task will not be fully confirmed as meeting the full MDE criteria until field verification, field measurements, and post field swale analysis are complete.

SCHEDULE

KCI will execute the task with completion and submission of all deliverables within approximately 4 months after the kickoff meeting.

COSTING

The total lump sum, fixed fee amount for the scope contained herein is **$109,028.00**. KCI will employ approved contract bill rates (which include planned direct expenses), and monthly invoicing amounts will be based on a percent complete total derived from the completion of each task. The manhour table following this page supports the pricing below.

Bill Rate	$ 175.00	$ 100.00	$ 78.60	$ 145.00	$ 118.00		
TASK DESCRIPTION	Project Manager	WR Engineer	CADD / GIS Technician	Sr. Geotech Engineer	Senior WR Engineer	HOUR TOTAL	TASK TOTAL
Task 1 - Project Initiation / Meetings	$ 1,400.00	$ -	$ -	$ 1,160.00	$ -		$ 2,560.00
Kickoff / Progress Meeting(s)	8			8		16	
Task 2 – Desktop Analysis	$ 12,600.00	$ 25,000.00	$ 37,728.00	$ -	$ -		$ 75,328.00
Organize GIS Data; DEM Processing; Desktop Analysis Workflow	72	250	480			802	
Task 3 – Potential Swale Quality Control	$ -	$ -	$ -	$ 7,540.00	$ 23,600.00		$ 31,140.00
Engineer Review				52	200	252	
TOTAL	80	250	480	60	200	1,070	$ 109,028.00
Total by Classification	$ 14,000.00	$ 25,000.00	$ 37,728.00	$ 8,700.00	$ 23,600.00		

PERCENT TASK DISTRIBUTION

TASK DESCRIPTION	TASK TOTAL	PERCENT
Task 1 - Project Initiation / Meetings		
Kickoff / Progress Meeting(s)	$2,560.00	2.35%
Task 2 – Desktop Analysis		
Organize GIS Data; DEM Processing; Desktop Analysis Workflow	$75,328.00	69.09%
Task 3 – Potential Swale Quality Control		
Engineer Review	$31,140.00	28.56%
TOTAL	**$109,028.00**	**100.00%**

MANHOUR ESTIMATES

TASK DESCRIPTION	Project Manager	Water Resource Engineer	Senior WR Engineer	CADD / GIS Technician	Sr. Geotech Engineer	TOTAL
Task 1 - Project Initiation / Meetings						
Kickoff / Progress Meeting(s)	8				8	16
Task 2 – Desktop Analysis						
Organize GIS Data; DEM Processing; Desktop Analysis Workflow	72	250		480		802
Task 3 – Potential Swale Quality Control						
Engineer Review			200		52	252
TOTAL	80	250	200	480	60	1,070

Watershed Restoration Projects

Barry Glassman
County Executive

Foster Branch at Dembytown Stream Restoration (WP000036)

Design Initated - Aug 2014 Construction Completed - Apr 2017

Near intersection of Dembytown Road and Trimble Road (ADC (2012) 56B7)

Design	Construction	Total Cost	Grant	Credits	Cost per Impervious Acre
$222,754 (24%)	$692,999 (76%)	$915,752	$500,000 (55%)	21.20 acres	$43,196

CIPid	Credits Type	Drainage Area (acres) / Impervious	Project Size	Credits (acres)	Credit Value
CIP0097	SWM Facility (RR)	28.4 (4%)	0.3 " rainfall treated	0.30	1 ac imp per 1" rainfall treated
CIP0036	Stream Restoration		2090 feet	20.90	0.01 ac imp per liner foot

Costs do not include County salaries for inspections or project management
Impervious Credits calculated based on "Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated", August 2014
RR = Runoff Reduction, ST = Stormwater Treatment (Source: 2000 Design Manual, MDE)

Wheel Creek at Country Walk 1B SWM Retrofit (WP000025)

Design Initated - Feb 2013 Construction Completed - Jun 2017

Near intersection of Wheel Road and Cinnabar Lane (ADC (2012) 49F4)

Installed new SWM wetland adjacent to existing instream SWM facility.

Design	Construction	Total Cost	Grant	Credits	Cost per Impervious Acre
$95,366 (18%)	$435,114 (82%)	$530,480	$121,623 (23%)	3.66 acres	$144,940

CIPid	Credits Type	Drainage Area (acres) / Impervious	Project Size	Credits (acres)	Credit Value
CIP0025	SWM Facility (ST)	9.72 (36%)	1.26 " rainfall treated	3.66	1 ac imp per 1" rainfall treated

Costs do not include County salaries for inspections or project management
Impervious Credits calculated based on "Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated", August 2014
RR = Runoff Reduction, ST = Stormwater Treatment (Source: 2000 Design Manual, MDE)

Harford County, MD Department of Public Works

Watershed Protection and Restoration

Watershed Restoration Status (MS4 Permit 11-DP-3310)

Barry Glassman County Executive

Active Projects

Wpid	Wpname	Wpcomplete (FY)	Total Credits (IA)
WP000027	Lower Wheel Creek SWM Retrofit & Stream Restoration	2018	66
WP000046	Leight Center Parking Lot Green Infrastructure	2018	1
WP000070	Abingdon Library Water Quality Improvements	2018	2
WP000074	Bear Cabin Branch Wetland and Stream Restoration	2018	37
WP000035	Ring Factory ES SWM Retrofit & Stream Restoration	2018	20
WP000088	Stormwater Retrofit at Homestead Elementary	2018	3
		Total	129
WP000029	Bynum at St Andrews Way Stream Restoration	2019	30
WP000033	Willoughby Beach SWM Retrofit & Stream Restoration	2019	33
WP000087	Tributary to Plumtree Run at Wakefield Manor Stream Restoration	2019	3
WP000014	Heavenly Pond Wetland & Stream Creation	2019	8
WP000086	Annie's Playground Stream Restoration	2019	30
WP000037	Foster Branch at Stillmeadow Stream Restoration	2019	22
WP000039	Plumtree Run at Barrington Stream Restoration	2019	32

WP000034	Church Creek ES SWM Retrofit & Stream Restoration	2019	24
WP000021	Sunnyview Drive Stream Restoration	2019	30
		Total	212
WP000085	Magnolia Elementary & Middle Campuses	2020	20
WP000043	Northwest Branch Declaration Run Stream Restoration	2020	20
		Total	40

Barry Glassman County Executive

Pending Projects

Wpid	Wpname	Wpcomplete (FY)	Total Credits (IA)
WP000089	Jarrettsville Elementary School Retrofit	2018	3
WP000069	Jarrettsville Highways Shop SWM Retrofit	2018	3
		Total	6
WP000092	Tributary to Winters Run at Brentwood Park Stream Restoration	2019	32
		Total	32
WP000091	C Milton Wright Stormwater Retrofit and Stream Restoration	2020	35
WP000090	Lilly Run Stream Restoration	2020	11
WP000098	Shamrock Run at Broadway Stream Restoration	2020	27
WP000097	Woodland Run Stream Restoration	2020	18
WP000099	Foster Branch at Pine Road Stream Restoration	2020	30
		Total	121

Harford County, MD Department of Public Works

Watershed Protection and Restoration

Watershed Restoration Status (MS4 Permit 11-DP-3310)

Barry Glassman
County Executive

	Thru FY2016	FY2017	FY2018	FY2019	FY2020	Total
Septic Pump Out (Average per year)	312.3	297.0	297.0	297.0	297.0	297.0
Connections to WWTP	3.2	2.7	2.7	2.7	2.7	14.1
Septic BAT Installation	29.4	7.0	7.0	7.0	7.0	57.5
Restoration	113.6	24.9	135.0	244.0	161.0	678.5
Total	458.5	331.7	441.8	550.8	467.8	1,047.1

Note: All values are impervious acres calculated using methods outlines in the "Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated", MDE 2014

Target = 20%	2,218.0
Balance	1,170.9
Target = 10%	1,109.0
Balance	61.9

HARFORD STREAMS

Printed 12/30/2017

Watershed Restoration Project Monitoring - Woodbridge

Woodbridge Year 1 Post-construction Monitoring

Pre-construction

Post-construction

Prepared for:
The Harford County
Department of Public
Works

December 20, 2016

Prepared by:
KCI Technologies Inc.
936 Ridgebrook Road
Sparks, MD
21152

KCI Job Number:
17134556.03

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Figures

Tables

Appendices

1. INTRODUCTION

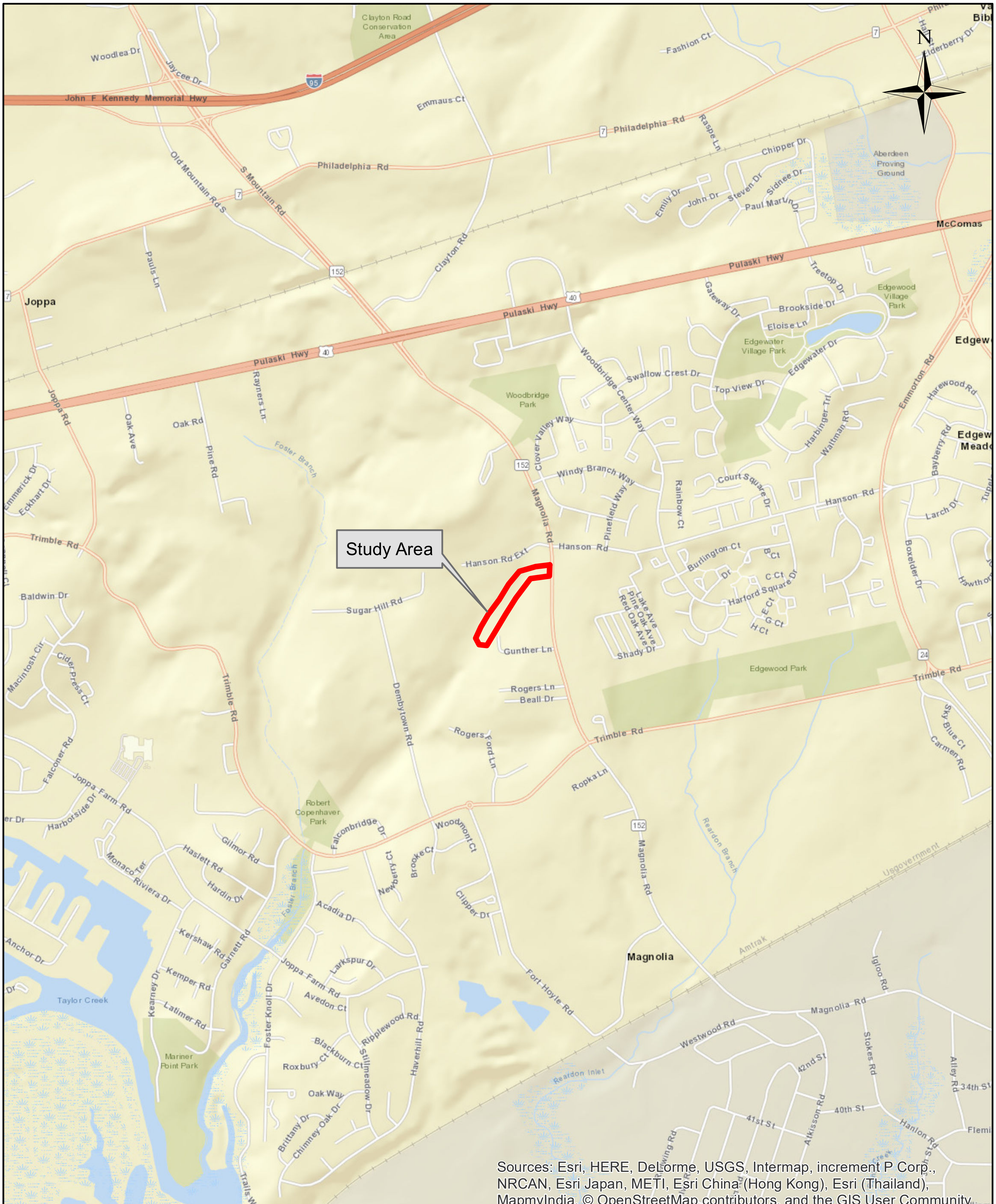
This report documents the first year of a three-year post-construction monitoring study for the stream restoration of an unnamed tributary to Foster Branch at Woodbridge. The project area is located in Joppatowne in southern Harford County, Maryland, and is situated southwest of the intersection of Magnolia Road (MD 152) and Hanson Road (see Figure 1, Project Vicinity Map).

Post-construction monitoring includes geomorphic, physical habitat, riparian buffer planting, biological assessments, and structure inspections. The Harford County Department of Public Works requested these services from KCI Technologies, Inc. (KCI) in order to assist with documenting the success of the restoration project that was completed in April 2015. Stream restoration monitoring will be conducted annually for three years, with assessments being completed in 2016 through 2018. The Year 1 geomorphic and biological monitoring surveys were conducted in April 2016, with a vegetation assessment completed in August 2016.

The main purpose of this study is to document and analyze the current and future stability of the restoration project and to support the County in its efforts to comply with the Woodbridge Stream Restoration Joint Permit (permit # 2011-60634-M24). Future yearly monitoring evaluations will supplement this data. Photographs of the site were taken and are included in Appendix A.

1.1. Restoration Design Description

The Woodbridge Stream Restoration project is 1,250 linear feet (LF) of stream restoration with a variety of stream stabilizing structures. The upstream portion of the project prior to restoration was highly degraded with 10-12 foot high banks. Private property adjacent to the extents of channel erosion made avoidance of impacts a challenge to design. The result is the Stepped Riffle Complex system that retains up to the 10-year discharge within the channel and drops over a steep gradient in a controlled manner for approximately 300 LF. The middle segment was several tortuous meanders that had too tight of radius of curvature, mature trees along both banks, and private property. Restoration in this segment consisted of 550 LF of riffle-pool sequence that was stabilized with riffle grade controls and stone toe protection. The last 30 LF consisted of a set of three step pools to bring the channel down to the elevation of the driveway culverts dictating channel elevation. The lower segment begins downstream of the culvert and contains 400 LF of minimal restoration efforts. The site conditions at the time of assessment and the general wish of the private property owner who owns the property was to leave the channel bed and left bank undisturbed during restoration after the immediate grade control downstream of the culvert. Only bank grading and stabilization with natural fiber matting and live stakes was to be conducted on the right bank for approximately 350 LF. At the end of this distance a stone sill was placed to mitigate any downstream disturbance from migrating up into the restoration area.



Woodbridge Stream Restoration
Post-Construction Monitoring
Figure 1. Vicinity Map
Harford County, Maryland
KCI Job No. 17134556.03

0 1,000 2,000 4,000 Feet

1" = 2000'

Legend

Study Area

METHODOLOGY

1.1. Monitoring Schedule

The Woodbridge site is being assessed annually for a period of three years around the same time each year. Data collected during Year 1 (2016) monitoring efforts shall serve as the baseline data to which future monitoring events will be compared. The monitoring assessment includes evaluations of riparian plantings, geomorphic assessments, physical habitat evaluation, biological monitoring, and structure inspections. Geomorphic and biological assessment locations can be seen in Figure 2, Site Assessment Location Map. Photographic documentation was collected during assessments for comparison of observations and can be referenced in Appendix A.

Stationing described in this report was coordinated with the design plan baseline, running from upstream to downstream, and will be referred to as the survey station. All assessments of bank and vegetation are approximate to the survey stationing. Right and left banks are designated facing downstream.

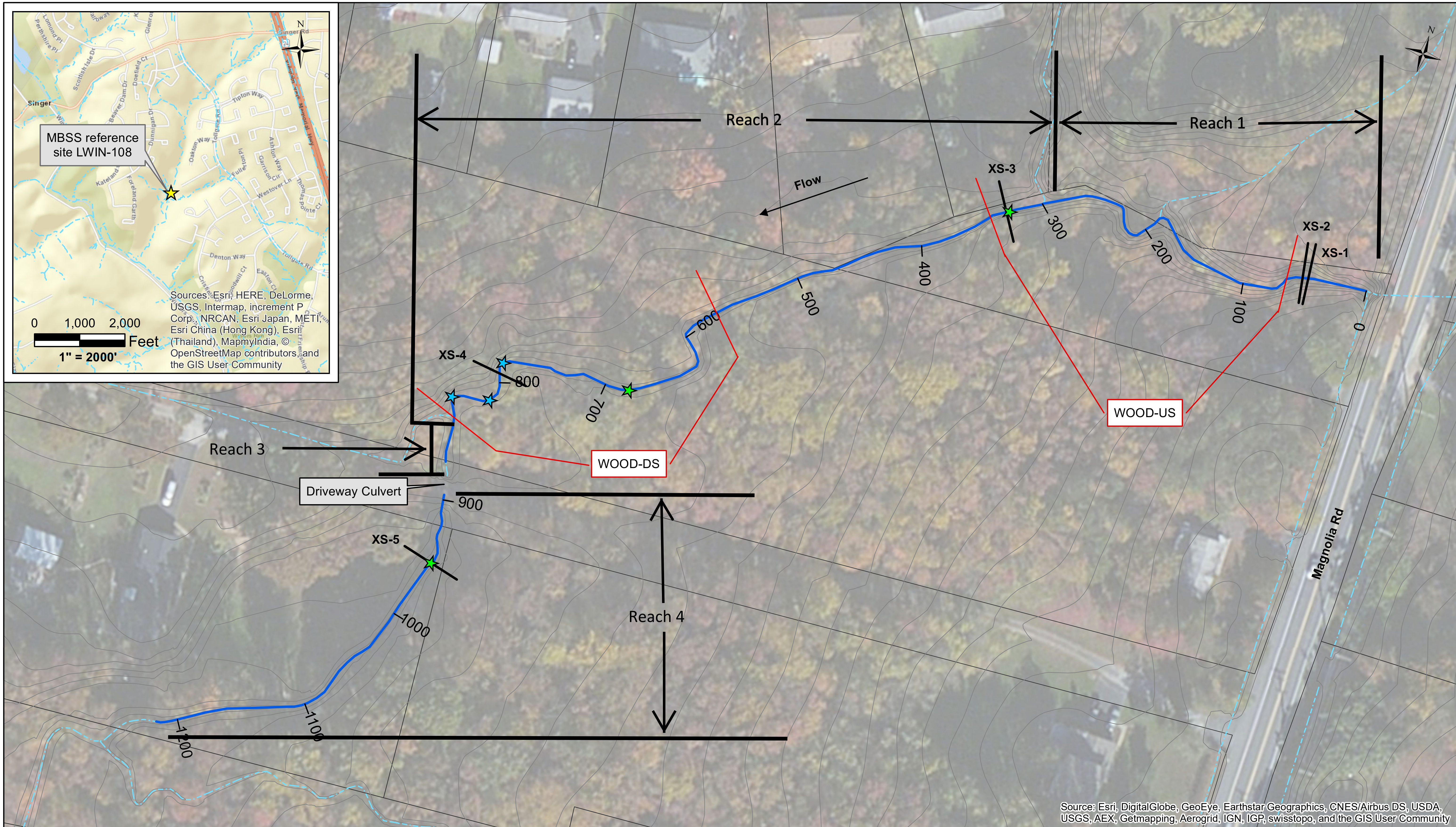
1.2. Riparian Planting Inspection

An inspection of riparian buffer plantings was completed to assess the establishment and survivability of riparian buffer plantings. Each planting zone was assessed according to the planting zones noted on the landscape plans. The planting zones were designed as either turf grass, reforestation, or live stake zones. Each planting zone was qualitatively assessed for overall health, survival, and establishment. Additionally, the planting zones were inspected to identify evidence of invasive species, infestation, disease, browsing, mortality, and the establishment of volunteer species. The percentage of survivability of live stakes on the stream banks was visually estimated. Survivability is defined as evidence of growth leading to the development of healthy leaves and roots.

During the above inspections, associated notes and photo documentation were taken to assess the overall functionality of vegetation along the stream banks. Functionality is defined as evidence of root growth that is maintaining the integrity of the stream bank. Areas where vegetative establishment within the project limits is sparse or non-existent may become prone to erosion. The photographic documentation is included in Appendix A-1.

1.3. Geomorphic Assessment

Geomorphic assessments include a longitudinal profile survey for the entire project length, 5 cross-sectional surveys, radius of curvature measurements, evaluation of sediment characteristics, and inspection of structures. The field procedures used for the geomorphic assessments were adapted from *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (Harrelson et al, 1994). Geomorphic assessments were completed to quantify basic stream characteristics including bed and bank stability as well as transport and deposition of bed materials. Cross-sectional and longitudinal profile surveys were conducted to compare future changes in the channel's hydraulic geometry over the course of the monitoring years. Photographic documentation is included in Appendix A-2.



Woodbridge Stream Restoration
Post-Construction Monitoring
Figure 2. Site Assessment Location Map
Harford County, Maryland
KCI Job No. 17134556.03

0 35 70 140 Feet
1" = 70'

Legend

- Restored Stream
- Other Streams
- Pebble Count Location
- Radius of Curvature Location
- Cross Section
- Biological Sampling Reach Limits
- 2' Contours
- Parcels

1.3.1. Cross-sectional Surveys and Longitudinal Profile Survey

Prior to beginning monitoring, five (5) permanent monumented cross sections were installed at locations along the study reach. Each monument consists of a 2 foot long rebar placed vertically into the ground and marked with a yellow cap, emblazed with "KCI NRM". In addition to these sections, a profile for the mainstem was established and surveyed. The 0+00 point is the culvert invert at the upstream extent of the project. The location of the channel and associated cross sections can be seen in Figure 2 Assessment Location Map.

Each cross section's elevation provided was tied to the pipe invert at the upstream start of the project site. Survey elevations of all cross sections were recorded at two-foot horizontal intervals outside the top of bank points and at one-foot horizontal intervals between the top of bank points. Cross-sectional data were plotted and analyzed for bankfull width, mean depth, width/depth ratio, cross-sectional area, and discharge. Future cross-sectional data will be overlaid with this baseline data for comparison purposes.

The low top of bank elevations identified in the field surveys were near to the designed bankfull elevations and were therefore designated as the bankfull elevations at the five corresponding cross sections to be monitored. These bankfull elevations are used to calculate each cross section's statistics, and will be used as permanent reference points from which to note future changes in cross-sectional geometry. The cross-sectional statistics were derived from a KCI developed Excel spreadsheet (KCI 2013) with calculations based on the Reference Reach spreadsheet (Mecklenburg 2006).

The longitudinal profile of the stream was surveyed to document constructed instream bed features that will aid in assessing the overall success of restoration at the site. The profile was established along the thalweg and included facet slopes, the water surface, and prominent features (e.g. crests, pools, riffles) where notable. Longitudinal profile data were used to calculate channel slope and document the current positioning of these bed features. Profile data was also analyzed and presented using the KCI (2013) spreadsheet.

1.3.2. Radius of Curvature Survey

The radius of curvature is a measurement utilized to evaluate channel resistance to erosion and bend or meander migration rates (Rosgen 1996). The radius of curvature was measured at three (3) meander bends between design stations 5+00 and 8+50 to track potential lateral channel migration. Radius of curvature measurements are taken via the cord length method (Leopold *et al.* 2000). The following locations are at the approximate center of each meander:

- Station 5+50
- Station 6+25
- Station 7+75

1.3.3. Bed and Bank Stability

The stability of the bed and banks are assessed in a variety of ways. Data from the cross sections, longitudinal and bank profiles and pebble counts will be used to look at changes over time.

A bank profile survey was conducted at three locations. The bank profile survey will be used instead of bank survey pins. This was determined to be the best method since there is gravel and cobble within the banks which is considered material unsuitable for bank pin evaluations due to disturbance during installation (Rosgen 2006). Additionally, bank pins were not installed since each bank is reinforced with stone toe protection making installation of bank pins infeasible. Channel-ward of the stone toe, bed pins were able to be installed and consisted of a 2 feet long rebar with yellow survey cap. Bank profiles will be replicated each year based on the measurement heights established in the Year 1 survey. The bank profiles were measured at the following locations:

- Station 3+55
- Station 6+54.5
- Station 8+09

Three (3) riffle pebble counts were conducted following standard methods by Wolman (1954) using the 100-count assessment. Pebble counts were taken at the following locations, shown in Figure 2:

- Station 3+28 (cross section 3)
- Station 6+88
- Station 9+53 (cross section 5)

1.3.4.Evaluation of Channel and Bank Stabilization Structures

A visual assessment of the Stepped Riffle Complex (SRC) structure, riffle grade control, stone sill, cascade crest, and stone toe protection was completed to evaluate the success of these stabilization structures. The assessment focused on observed structural integrity of the stabilization techniques noting evidence of deterioration, dislodgement, etc. Typical areas of concern include locations where shifting, scouring, and undercutting compromises the stability of the structures. In addition, the function and performance of each structure within the restoration reach was qualitatively assessed. This assessment can be used to pinpoint the areas of concern and recommend appropriate remedial actions as necessary. Photographic documentation of these areas is included in Appendix A-3.

1.4. Physical Habitat Evaluation

Physical habitat was evaluated at two (2) biological monitoring sites (see Figure 2). The biological monitoring sites were characterized based on visual observations of physical characteristics and various habitat parameters. The EPA's Rapid Bioassessment Protocol (RBP) habitat assessment for low gradient streams (Barbour et al., 1999) and the Maryland Biological Stream Survey's (MBSS) Physical Habitat Index (PHI; Paul et al., 2003) were used to assess the physical habitat at each site. Both assessment techniques rely on subjective scoring of selected habitat parameters. To reduce individual sampler bias, both assessments were completed as a team with discussion and agreement of the scoring for each parameter. In addition to the visual assessments, photographs were taken from three locations within each sampling reach (downstream end, mid-point, and upstream end) facing in the upstream and downstream direction, for a total of six (6) photographs per site (Appendix A-4).

The RBP habitat assessment consists of a review of ten biologically significant habitat parameters that assess a stream's ability to support an acceptable level of biological health (Table 1). Each parameter is given a numerical score from 0-20 (20 = best, 0 = worst), or 0-10 for individual bank parameters (i.e., bank stability, vegetative protection, and riparian vegetative zone width), and a categorical rating of optimal, suboptimal, marginal or poor. Overall habitat quality typically increases as the total score for each site increases.

Table 1. RBP Low Gradient Habitat Parameters

Low Gradient Stream Parameters	
Epifaunal substrate/available cover	Channel alteration
Pool substrate characterization	Channel sinuosity
Pool variability	Bank stability
Sediment deposition	Vegetative protection
Channel flow status	Riparian Vegetative Zone Width

The RBP habitat parameters for each reach are summed, with a total possible score of 200. The total score is then placed into one of four narrative categories (Table 2) based on the percent comparability to reference conditions.

Table 2. RBP Habitat Score and Ratings

Score	Percent of Reference	Narrative Rating
≥180	≥90%	Comparable to Reference
150-179	75% - 89%	Supporting
120-149	60% - 74%	Partially Supporting
≤119	≤60%	Non-Supporting

The PHI incorporates the results of a series of habitat parameters selected for Coastal Plain, Piedmont and Highlands regions. While all parameters are rated during the field assessment, the Coastal Plain parameters are used to develop the PHI score. In developing the PHI, MBSS identified six parameters that have the most discriminatory power for coastal plain streams. These parameters are used in calculating the PHI (Table 3). Several of the parameters have been found to be drainage area dependent and are scaled accordingly.

Table 3. PHI Coastal Plain Parameters

Coastal Plain Stream Parameters	
Remoteness	Instream Habitat
Shading	Woody Debris and Rootwads
Epibenthic Substrate	Bank Stability

Each habitat parameter is given an assessment score ranging from 0-20, with the exception of shading (percentage) and woody debris and rootwads (total count). A prepared score and scaled score (0-100) are then calculated. The average of these scores yields the final PHI score. The final scores are then ranked according to the ranges shown in Table 4 and assigned corresponding narrative ratings, which allows for a score that can be compared to habitat assessments performed statewide.

Table 4. PHI Score and Ratings

PHI Score	Narrative Rating
81.0 – 100.0	Minimally Degraded
66.0 – 80.9	Partially Degraded
51.0 – 65.9	Degraded
0.0 – 50.9	Severely Degraded

1.5. Biological Monitoring

Benthic macroinvertebrate sampling was conducted at the two established biological monitoring sites: Wood-US and Wood-DS (see Figure 2). Samples were collected following MBSS protocols (MDNR, 2014) by field personnel certified by MDNR in MBSS sample collection procedures. Benthic macroinvertebrate samples were processed and identified according to methods described in *MBSS Laboratory Methods for Benthic Macroinvertebrate Processing and Taxonomy* (Boward and Friedman, 2000) by Environmental Services & Consulting, LLC. Identification of the specimens is conducted to the genus level for most organisms. Groups including Oligochaeta and Nematomorpha were identified to the family level while Nematoda was left at the phylum. Individuals of early instars or those that may be damaged are identified to the lowest possible level, which could be phylum or order but in most cases would be family.

Benthic macroinvertebrate data were analyzed using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland* Streams (Southerland et al., 2005). The Benthic Index of Biotic Integrity (BIBI) approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. The metrics selected fall into five major groups including taxa richness, composition measures, tolerance to perturbation, trophic classification, and habit measures. The current study area is located within the coastal plain physiographic region; therefore, the coastal plain BIBI was calculated for data analysis. Raw values from each metric are given a score of 1, 3 or 5 based on ranges of values developed for each metric as shown in Table 5. The results are combined into a scaled BIBI score ranging from 1.0 to 5.0 and a corresponding narrative rating is assigned (
Table 6).

Table 5. Biological Condition Scoring for the Coastal Plain Benthic Macroinvertebrates

Metric	**Score**		
	5	**3**	**1**
Total Number of Taxa	≥22	14-21	<14
Number of EPT Taxa	≥5	2-4	<2
Number of Ephemeroptera Taxa	≥2.0	1-1	<1.0
Percent Intolerant Urban Taxa	≥28	10-27	<10.0
Percent Ephemeroptera Taxa	≥11	0.8-10.9	<0.8
Number Scraper Taxa	≥2	1-1	<1.0
Percent Climber Taxa	≥8.0	0.9-7.9	<0.9

Table 6. BIBI Scoring and Rating

BIBI Score	**Narrative Rating**
4.0 – 5.0	Good
3.0 – 3.9	Fair
2.0 – 2.9	Poor
1.0 – 1.9	Very Poor

2. MONITORING YEAR 1: RESULTS AND DISCUSSION

2.1. Riparian Planting Inspection

An inspection of the riparian buffer plantings at the site was completed on August 4, 2016. The majority of surviving plants appear healthy and free of insects and diseases. Photo documentation of the bank and riparian buffer planting inspections is presented in Appendix A-1.

Live Stake Zone

In general, the live stake bank plantings showed vigorous growth and were very healthy. The bank plantings included four species of live stakes (gray dogwood, silky dogwood, black willow, and streamco willow). Typically dogwood species (*Cornus* sp.) are much slower growing than willow species (*Salix* sp.), however all species were equally vigorous throughout the site. Japanese beetles were noted on the willow live stakes, but did not appear to be causing significant damage to the plants at the time of the inspection. Average survival ranged from 90-100% throughout the site. However, one location had extremely poor survival at less than 10% between station 9+50 to 10+00. Survival is low as a result of the bank erosion on the right bank. Many stakes have fallen from the bank.

Live stakes were substituted for the live branch layers specified on the landscape plans and assessment of these live stakes were included in the overall live stake zone assessment.

Reforestation Zone

The trees and shrubs of the reforestation zone had excellent survival and vigor. The overall survival of trees was estimated at 99% and shrub survival was estimated at 95%. All tree species were healthy, however American sycamore, tulip poplar, and river birch were found to be the most vigorous species. All tree shelters were in place and effective. Spicebush shrubs were the most vigorous of the shrub species. Some insect herbivory was observed on the arrowwood viburnum, however it is expected that the shrubs will survive.

Some minor dieback was observed in the existing mature trees, particularly at the upstream end of the site, likely as a result of construction stressors. These trees should be monitored carefully and removed if necessary to avoid uprooting and bank instability.

Many volunteer seedlings were observed in the reforestation zone, including sweet gum and tulip poplar trees.

Turf Grass and Permanent Seeding Zones

Two turf grass zones were established in lawns adjacent to the stream. Overall, turf grass coverage was 93%. Turf grass zones were being maintained by the homeowners.

Permanent seeding was established throughout the live stake and reforestation zones. Overall coverage was estimated 85%. Poor establishment was noted from stations 0+00 to 2+25, where bare areas of gravel and sediment were found. This poor establishment may be a result of road runoff from Magnolia Road. Downstream from the tributary on the right bank at station 2+25, average coverage is 96%. Switchgrass, deertongue grass, and fringed brome were the most vigorous of the planted species. Many volunteer species were found in the herbaceous layer of the reforestation zone, including sedges, rushes, and hay-scented fern. Jewelweed and beggarticks were found robustly growing in the channel throughout the site.

Invasive species

Invasive species were noted throughout the site, but in minimal densities. Invasive species noted include Mimosa tree, Chinese lespedeza, clover species, common ragweed, princess tree and Japanese stiltgrass. At this point, they are not competing with the planted species for resources. Many invasive species observed within the site were also observed beyond the limits of disturbance in wooded areas; thus, their presence in a recently disturbed site is expected. Invasive species have the potential to overwhelm the native species, and will be monitored closely in the following year's surveys for an increase in their population and coverage. The princess trees were growing under the powerlines along the driveway to 616 Magnolia Road and should be removed. No other eradication is recommended.

2.2. Geomorphic Assessment

2.2.1. Cross-sectional Surveys

Cross-sectional surveys were analyzed for bankfull width, mean depth, width/depth ratio, cross-sectional area, and discharge. These measurements are presented in Table 7 and graphical depictions of each cross section are presented in Appendix B. Bankfull elevations measured in the field match the top of the bank height associated with the design discharge at each cross section, and were therefore used to calculate the statistics presented in Table 7.

Cross sections 1 and 2 were established within the SRC at the upstream end of the restoration channel. Cross section 1 monitors a weir, while cross section 2 was established at a pool. Monitoring both features within the SRC will allow for a thorough analysis of the long term stability of the SRC system as a whole.

Cross sections 3 and 4 are located within the middle section of restoration, which utilized riffle-pool sequences. Cross section 3 was established in a riffle with riffle grade control stabilizing the channel bed. Cross section 4 is located across a pool, with stone toe protection stabilizing the right bank.

Cross section 5, located downstream of the driveway culvert, is in an area of stream that was minimally restored through grading of the right bank only. As a result the cross section is much wider than the restored cross section.

Table 7. Cross-sectional Analysis Statistics

Cross Section	Station	Feature	Bankfull Width (ft)	Mean Depth (ft)	Cross-Sectional Area (ft^2)	Width-Depth Ratio	Discharge (cfs)
1	0+43	SRC Weir	8.8	0.8	6.7	11.5	40.1
2	0+47	SRC Pool	11.6	1.5	17.8	7.6	164.9
3	3+28	Riffle	8.3	0.9	7.9	8.8	36.3
4	8+00	Pool	7.4	1.1	7.8	6.9	34.2
5	9+53	Riffle	11.3	1.3	14.8	8.6	79.7

At this time, and without multiple years to compare to, the cross sections appear to be stable with no undercut banks. Comparison with future monitoring events will indicate lateral migration and general bed movement.

2.2.2. Longitudinal Profile Survey

An analysis of the surveyed longitudinal profile allowed for the reach slopes to be calculated along the restored channel. Reaches and their corresponding slopes can be seen in Table 8 below.

Table 8. Longitudinal Profile Slope Comparison

Reach	Feature	Extent	Slope Year 1
1	SRC	Station 0+16 to 2+99	5.27%
2	Channel between SRC and step pools	Station 3+28 to 8+12	1.74%
3	Step Pools	Station 8+12 to 8+61	5.10%
4	Downstream of driveway culverts	Station 9+00 to 12+00	1.59%

Reach 1, through the SRC system, was designed with a steep slope due the constraints of adjacent private property and a high degree of channel entrenchment. The SRC allows the channel to have a higher slope while maintaining stability. Reach 2 begins immediately downstream of the SRC and extends downstream until just prior to the step pools. Reach 4 is the short step pool segment ending at the culvert invert. Reach 4, which was minimally restored, begins downstream of the driveway culvert and installed plunge pool and continues to the end of the restoration to the installed sill.

The surveyed longitudinal profiles are included in Appendix C and will be used as the baseline data for comparison with future monitoring events.

2.2.3. Radius of Curvature Survey

The radius of curvature was measured at three (3) meander bends to track potential lateral channel migration, with results in Table 9:

Table 9. Radius of Curvature Results

Meander Location	Radius (feet)
Station 5+50	32
Station 6+25	37
Station 7+75	57

2.2.4. Bed and Bank Stability

In general, the sediments of the mainstem's channel bed include coarse gravel to large cobble. The same material was used in the pools and riffles. Some bed material was observed to have migrated downstream forming a sediment bar near station 6+75. Bed and most bank scour is limited to the areas noted within close proximity to structures and is therefore discussed in the next section. One area of bank erosion is the largely unrestored segment from approximately 9+20 to 12+50. The right bank was graded to a 2:1 slope and stabilized with natural fiber matting and live stakes. At the time of the visual assessment of this area the live stakes that were still within the bank had not yet grown, the matting stakes were no longer fully sunk into the soil leaving the matting loose, and the bank was largely unprotected. It was unclear if there had been soil loss around the stakes or if the matting stakes had been elevated from soil heaving actions. The matting stakes are recommended to be reinstalled to help re-secure the matting and stabilize the bank without further action.

Pebble count results from the 3 riffles are provided in Table 10. The particle size distribution charts are included in Appendix D. The material collected from cross section 3, in a riffle grade control, is similar to the material specified for in the riffle grade control design. This is most noticeable at the top and bottom end of the size distribution, but becomes slightly less matched with the design specifications at the middle of the size range. This middle segment is slightly undersized based on the design specifications. The sizing found at pebble counts 2 and 3, within channel bed material, is also fairly well aligned with the channel bed material called for in the design. Designed size ranges for both riffle grade controls and channel bed material are included in Appendix D.

Table 10. Pebble Count Material

Pebble Count ID	Location	Channel Material	Particle Size Distribution (mm)					
			D_{16}	D_{35}	D_{50}	D_{65}	D_{84}	D_{95}
1	XS 3	Riffle Grade Control	17	32	47	82	140	210
2	Station 6+88	Channel Bed Material	17	29	42	75	120	180
2	XS 5	Channel Bed Material	9.5	29	41	73	130	180

2.2.5. Evaluation of Channel and Bank Stabilization Structures

Stepped Riffle Complex (SRC)

The SRC was constructed from station 0+00 to 3+10, and includes a sequence of 16 pool, riffle-weir complexes. The entire SRC was inspected as a complete structure. SRC weirs are composed of boulders and appear stable throughout the system. SRC Pools were composed of a riffle grade control material. Overall the SRC pools are stable, though it looks that some movement of material has occurred throughout. In SRC pool 1 there appears to be some material that is not in contact with the surrounding materials as is throughout the pools, indicating they may have been mobilized at some point. Their movement has not created any areas of instability so the movement is not of concern.

Riffle Grade Control

The riffle grade control (RGC) uses sediments that were sized to resist a greater critical shear stress than boundary shear stress. This would therefore stabilize the channel bed and maintain its grades. The riffle grade controls were constructed between stations 3+12 and 3+40; 4+25 and 4+45; 5+00 and 5+25; 5+60 and 5+75; 6+50 and 6+80; 8+00 and 8+18; and 8+89 and 9+14.6. Upon inspection, all RGC structures appeared stable. The only other RGC with something worth noting is the downstream tie-in to existing grade at station 9+15. The tie-in is slightly elevated making a rise in the RGC bed which may produce scour over time within the existing bed.

Stone Sill

Stone sills were constructed at stations 9+00 and 12+00. The sill at 9+00 is stable and the scour pool directly downstream is also stable. The sill at 12+00 is located at the downstream extent of the restoration project. This structure is not failing but it is showing some signs of possible instability. This includes the separation of the sill stones, slight tilt to one of the central stones and scour at the downstream side of the sill. Additionally, the weir was installed at grade to the downstream existing bed when constructed, however, a scour hole is now visible for 8 feet downstream of the sill with overall channel downcutting visible. The signs of instability in the sill may be a result of shifting based on stopping the overall channel downcutting that has occurred, which was the purpose of this structure.

Step Pools

A series of three step pools were placed from 8+18 to 8+51 with crests at stations 8+18, 8+26, 8+34, 8+42, and 8+51. Each crest was observed to be stable, however, most of the pools were partially or fully filled with fine sediments or leaf litter. This is not anticipated to affect the stability as this material will be easily mobilized during a high flow event when the pools are scoured and needed for energy dissipation.

Stone Toe Protection

Stone toe protection was placed in the mainstem along the outer bends of meanders, along some of the riffle grade control structures, and where a drainage enters the stream. On the left bank, this includes from station 5+92 to 6+80. On the right bank, this includes from stations 4+65 to 5+75; and 7+25 to 8+20. The stone toe protection is designed to harden the banks and prevent erosion and lateral migration of the channel. The majority of stone toe protection materials are sufficiently large with no indication of dislodging. However, in two locations the up or downstream key-in to a non-stone bank is of minor concern. The upstream key-in at 4+65 on the right bank shows some scour and the downstream tie-in at 5+75 is elevated such that it has a high potential for inducing scour under some flow conditions. Despite this, no portions of the stone toe appear to be slumping or failing. Thus far, all stone toe protection is functioning as designed, but will be visually monitored for movement and erosion behind the stones.

2.3. Physical Habitat Evaluation

Physical habitat evaluations were conducted concurrently with biological sampling on April 15, 2016. The summary results of the RBP and PHI habitat assessments are presented in Table 11. Complete habitat assessment results are presented in Appendix E. The percent comparability to RBP reference scores ranged from 52.0 percent at WOOD-US to a high of 57.5 percent at site WOOD-DS, with both sites receiving classifications of 'Non-Supporting.' The MBSS reference site, LWIN-108, was not evaluated using the RBP method. Similar assessment results were observed using the PHI index, where site WOOD-US received the lowest score of 55.18 and a narrative rating of 'Degraded' and site WOOD-DS received the highest score of 60.32 and a rating of 'Degraded.' The MBSS reference site (LWIN-108) was also rated as 'Degraded,' with a PHI score of 62.70.

Table 11. Physical Habitat Assessment Results 2015

Site	Total RBP	RBP % of Reference	RBP Classification	PHI Score	PHI Narrative Rating
WOOD-US	104	52.0	Non-Supporting	55.18	Degraded
WOOD-DS	115	57.5	Non-Supporting	60.32	Degraded
LWIN-108	n/a	n/a	n/a	62.70	Degraded

n/a = not applicable

A comparison of post-construction results from 2015, to pre-construction data from 2005 – 2007 is presented below in Figure 3. Both sites show slightly improved PHI scores compared with pre-construction conditions. There is no longer a downward trend of declining habitat scores, most of which were previously attributed to accelerated bank erosion and sedimentation. It is likely that the PHI scores will improve once the vegetation begins to fill in, improving shading and woody input to the stream channel.

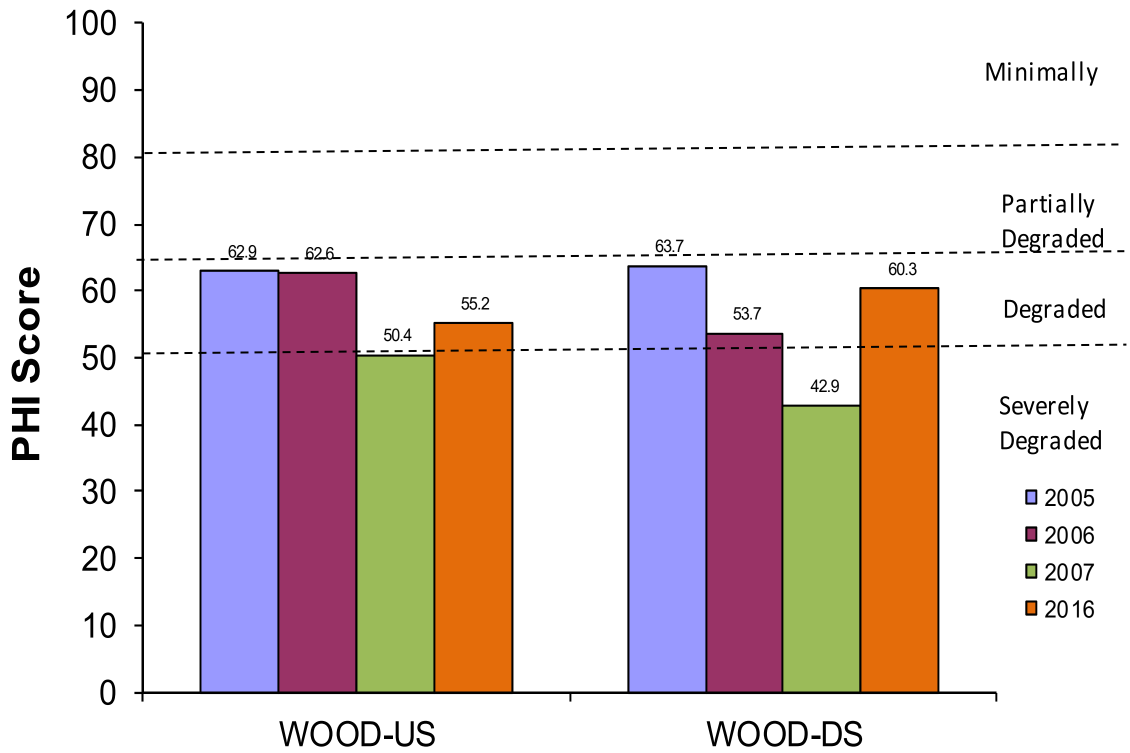


Figure 3. Comparison with Pre-Construction (2005-2007) PHI Scores

2.4. Biological Monitoring

Benthic macroinvertebrate sampling was conducted at the two (2) biological monitoring sites on April 15, 2016. Both sites received 'Very Poor' biological condition ratings, with BIBI scores ranging from 1.00 to 1.86. At the downstream restoration reach, WOOD-DS, there were 125 individuals identified in the sample, comprising only 11 taxa. The sample was dominated by Naididae (Tolerance Value [TV] = 8.5), a family of pollution tolerant oligochaete worms. There were only 2 EPT Taxa present and no ephemeroptera taxa. Only one scraper taxa was present, and both intolerant individuals and climbers were present in very low amounts, 2.0% and 3.2%, respectively. The upstream restoration reach, WOOD-US, also had only 11 taxa present in the 116-organism subsample. Only a single EPT taxon was present, and ephemeroptera and scraper taxa were both absent. Like WOOD-DS, the sample was dominated by pollution tolerant oligochaete worms.

Table 12. Benthic Index of Biotic Integrity (BIBI) Summary Data 2016

Metric	WOOD-DS	WOOD-US
Metric Values		
Total Number of Taxa	11	11
Number of EPT Taxa	2	1
No. of Ephemeroptera Taxa	0	0
Percent Intolerant Urban	2	0
Percent Ephemeroptera	0.0	0
Number Scraper Taxa	1	0
Percent Climbers	3.2	0
Metric Scores		
Total Number of Taxa	1	1
Number of EPT Taxa	3	1
No. of Ephemeroptera Taxa	1	1
Percent Intolerant Urban	1	1
Percent Ephemeroptera	1	1
Number Scraper Taxa	3	1
Percent Climbers	3	1
BIBI Score	**1.86**	**1.00**
Narrative Rating	**Very Poor**	**Very Poor**

Results from the MBSS reference site (LWIN-108), which was sampled during the spring 2015 index period, are presented in Table 13. It is worth noting that the pre-construction reference site was not able to be sampled due to issues with property owner permissions, and that a nearby MBSS urban reference reach has been selected to serve as the new reference site moving forward. This site is located in the adjacent Winters Run watershed, however, it is within the piedmont physiographic region. Subsequently, the MBSS piedmont were used to calculate the BIBI score. Overall, the site received a BIBI score of 3.00 and a corresponding narrative rating of 'Fair.' The 120-organism subsample was represented by 28 taxa, eight (8) of which were EPT taxa. One ephemeroptera taxon, *Eurylophella* (TV = 4.5), was present in the sample. Intolerant individuals comprised 29% of the sample, and clingers comprised 69%.

Table 13. MBSS Reference Site Benthic Index of Biotic Integrity (BIBI) Summary Data 2016

Metric	LWIN-108
Metric Values	
Total Number of Taxa	28
Number of EPT Taxa	8
Number of Ephemeroptera Taxa	1
Percent Intolerant Urban	29
Percent Chironomidae	44
Percent Clingers	69
Metric Scores	
Total Number of Taxa	5
Number of EPT Taxa	3
Number of Ephemeroptera Taxa	1
Percent Intolerant Urban	3
Percent Chironomidae	3
Percent Clingers	3
BIBI Score	**3.00**
Narrative Rating	**Fair**

A comparison of post-construction results from 2015, to pre-construction data from 2005 – 2007 is presented below in Figure 4. It is important to note that both sites had to be shifted slightly in 2015 from the previously established locations as a result of the stream restoration activities. The upstream site was shifted from above Magnolia Road in the pre-restoration phase to immediately below Magnolia Road in the post-restoration phase. Therefore, comparisons in BIBI scores between pre- and post-construction periods need to account for this difference. WOOD-DS shows fairly consistent BIBI scores from pre- to post-construction conditions. WOOD-US, on the other hand, shows a decline in post-construction BIBI scores. However, even at the reference site, deviations occur in the BIBI scores from year-to-year resulting from natural variation (see Figure 5). Although, it is also likely that the BIBI scores will improve once the benthic macroinvertebrate community has an opportunity to recover from the disturbance caused by the stream construction.

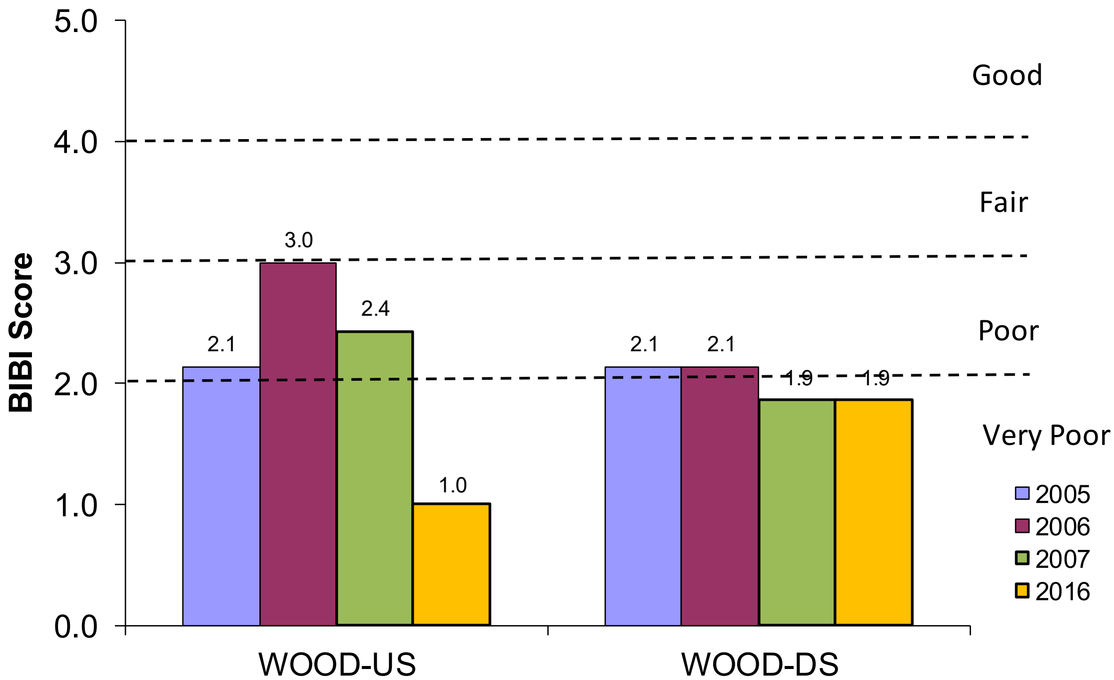


Figure 4. Comparison with Pre-Construction (2005-2007) BIBI Scores

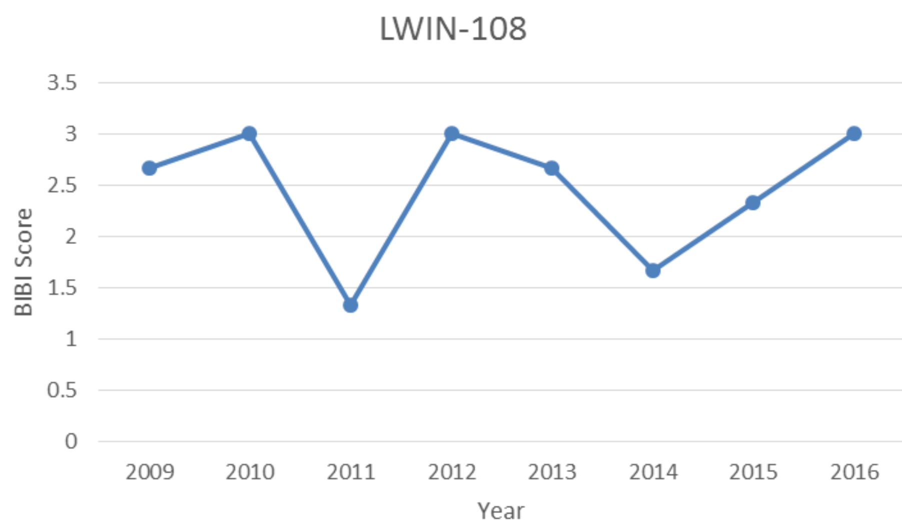


Figure 5. Comparison of BIBI Scores at the MBSS Reference Site (2009-2015)

3. CONCLUSIONS

The Year 1 (2016) geomorphic monitoring and structure inspections show a stream channel that is overall stable and functioning as designed. The few areas of erosion near the RGC, stone toe protection key-in should be specifically observed for increased deterioration. It is possible these areas will stabilize over the next year due to the increase in vegetative development. The right bank of the unrestored segment approximately 9+20 to 10+00 should be rematted, or stakes reset to secure the existing matting. The stone sill at 12+00 showed the greatest potential of failure yet its purpose is to mitigate such deterioration. No action is recommended at this time for the downstream sill due to its potential to stabilize with increased vegetation growth, lack of immediate cascading failures upstream if it were to fail and location on private property.

Overall, all planted landscape zones were extremely vigorous and successful. Trees, shrubs, and live stakes all had excellent survival and were found to be in excellent health. Aside from the poor herbaceous survival at the upstream end on the right bank, likely due to road runoff, the herbaceous zone and turf grass zones were very successful and had excellent coverage. All zones passed the warranty survival requirement of 85%. Minimal invasive species were noted, however the princess trees under the power lines should be removed. It is recommended that the area downstream of the culvert on the right bank from 9+50 to 10+00 be replanted with live stakes. Additionally, the existing mature trees should continue to be monitored for signs of construction stressors.

Impacted biological and physical habitat conditions are currently present following construction of the stream restoration project. These results are expected since it often takes time for the macroinvertebrate community to recover following a substantial disturbance, such as construction of a new stream channel. Furthermore, physical habitat conditions have also been impacted by the recent construction, and it will also take time for the vegetation to thrive and create more heterogeneous and functional habitat conditions within and around the channel. Biological potential is limited by the quality of the physical habitat, which forms the template upon which biological communities develop (Southwood, 1977). As the habitat conditions improve and the benthic macroinvertebrate community begins to recolonize the stream, it is expected that improvements to the biological conditions will be seen during future assessments.

4. REFERENCES

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APPENDIX A
Site Photographs

Right and left banks are determined facing downstream

Facing upstream of poor establishment in turf grass zone near road at station 0+00

View facing downstream of excellent tree survival and poor herbaceous establishment in riparian zone on right bank from station 0+00

View facing upstream from station 0+25

View facing downstream of excellent live stake growth from station 0+25

View facing left bank of excellent live stake growth from station 2+00

View of poor herbaceous establishment on right bank from station 2+00

View facing upstream tributary on right bank at station 2+25

View facing downstream of vigorous live stake growth from station 2+25

View facing upstream tributary on right bank at station 2+75

View facing upstream turf grass zone on right bank from station 2+75

View facing downstream of vigorous live stakes and vegetation in channel from station 2+75

View facing downstream riparian zone on left bank from station 2+75

Right and left banks are determined facing downstream

View facing upstream of vigorous herbaceous establishment in riparian zone from station 4+00

View facing downstream of excellent tree and shrub survival on left bank from station 4+00

View facing left bank of sedge and rush volunteers in riparian zone from station 4+50

View of bare spot around existing trees on left bank from station 5+25 to 5+50

View facing downstream of dense deer tongue grass on right bank from station 5+50

View facing downstream of dense jewelweed in channel from station 6+00

View of skeletonized viburnum leaves, likely from viburnum leaf beetle or Japanese beetle

View facing downstream from station 7+00

View facing downstream riparian zone from station 7+00

View facing upstream tributary on right bank from station 7+40

View facing right bank of vigorous willow live stakes from station 7+75

View facing upstream of princess trees at driveway road culvert

View of turf grass zone on upstream side of road culvert

View facing downstream from driveway road culvert

View of riparian zone on left bank at driveway road culvert

View facing downstream of eroded right bank and dead live stakes from station 9+50 to 10+00

View facing right bank turf zone from station 9+75

View facing upstream from station 10+00

View facing downstream from station 10+00

View facing upstream from station 11+25

Right and left banks are determined facing downstream


Station 0+00 facing downstream; culvert invert


Station 0+09 facing downstream


Station 0+43 at cross section 1 facing downstream


Station 0+43 at cross section 1 facing left bank


Station 0+43 at cross section 1 facing right bank


Station 0+47 at cross section 2 facing downstream


Station 0+47 at cross section 2 facing left bank


Station 0+47 at cross section 2 facing right bank

Right and left banks are determined facing downstream

Station 0+55 facing downstream

Station 0+70 facing downstream

Station 1+40 facing downstream

Station 1+71 facing downstream

Right and left banks are determined facing downstream

Station 1+90 facing downstream

Station 2+25 facing downstream; pool and downstream riffle are dry

Station 2+60 facing downstream

Station 2+87 facing downstream; tributary confluence on right bank

Right and left banks are determined facing downstream

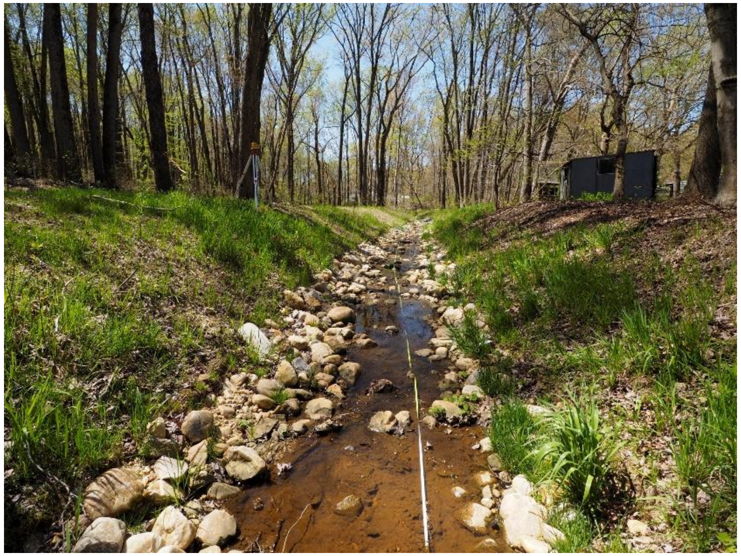
Station 2+92 facing downstream

Station 3+28 at cross section 3 facing downstream

Station 3+28 at cross section 3 facing left bank

Station 3+28 at cross section 3 facing right bank

Right and left banks are determined facing downstream



Station 3+46 facing downstream

Station 3+72 facing downstream

Station 4+65 facing downstream

Station 5+05 facing downstream

Right and left banks are determined facing downstream

Station 5+50 facing downstream

Station 5+81 facing downstream

Station 6+10 facing downstream

Station 6+55 facing downstream

Station 7+32 facing downstream

Station 8+00 at cross section 4 facing downstream

Station 8+00 at cross section 4 facing left bank

Station 8+00 at cross section 4 facing right bank

Station 8+25 facing downstream

Station 8+40 facing downstream towards driveway culvert

Station 8+85 at downstream end of driveway culvert facing downstream

Station 9+00 facing downstream


Station 9+53 at cross section 5 facing left bank


Station 9+53 at cross section 5 facing right bank


Station 9+53 at cross section 5 facing downstream


Station 9+70 facing downstream

Station 10+00 facing downstream

Station 10+20 facing downstream

Station 10+40 facing downstream

Station 11+20 facing downstream

Right and left banks are determined facing downstream

Station 11+40 facing downstream

Station 11+80 facing downstream

Station 12+00 at weir facing downstream

Station 12+25 facing downstream

Station 0+10 facing left bank; possibly dislodged stones from pool

Station 0+80 facing left bank; cut tree in channel

Station 1+75 facing downstream; stepped riffle complex weirs look stable

Station 2+25 facing right bank; pool and downstream riffle are dry

Station 2+50 facing right bank; cobble material potentially pushed up/out of pool

Station 2+87 facing right bank at tributary confluence; tributary tie-in is stable

Tributary facing left bank; upstream key-in is stable

Tributary facing right bank; upstream key-in is stable

Station 3+20 facing downstream; riffle grade control is stable

Station 3+50 facing downstream; minor left bank scour just downstream of riffle grade control

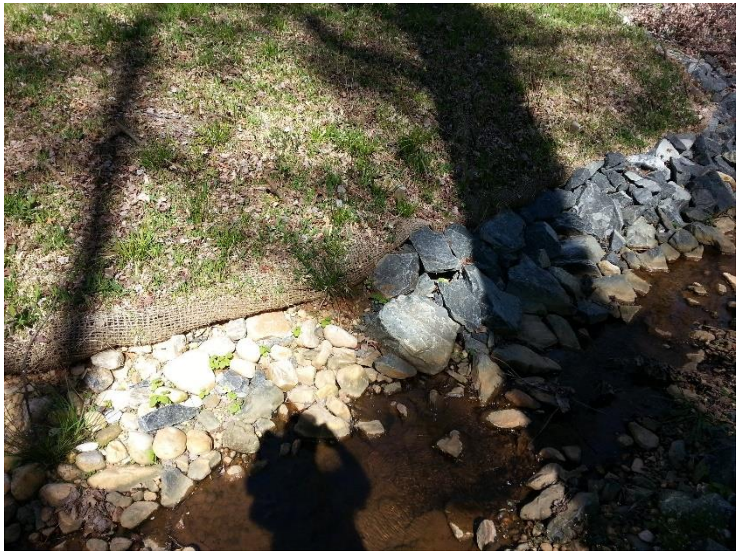
Station 3+50 facing left bank; minor bank scour just downstream of riffle grade control

Station 4+25 facing downstream; riffle grade control stable with good side slope correction; no scour at downstream end

Station 4+65 facing right bank stone toe protection; small scour at key-in but cause uncertain, otherwise stable

Station 4+95 facing downstream; riffle grade control and stone toe protection stable

Station 5+50 facing downstream; riffle grade control stable with good blended appearance



Station 5+80 facing right bank; stone toe protection tie-in a little perched

Station 5+90 facing left bank; stable stone toe protection tie-in

Station 6+30 facing downstream; point bar formation/tailout

Station 6+50 facing downstream; riffle grade control stable

Station 6+90 facing right bank; transition between stone toe protection and channel bed material

Right and left banks are determined facing downstream

Station 7+51 facing right bank seep channel; tie-in is stable

Station 7+51 facing downstream; stone toe protection and seep channel tie-in is stable with some deposition

Station 7+90 facing downstream; stone toe protection more “stacked” than laid back, but stable

Station 8+30 facing downstream at debris collector installed by property owner

Station 8+27 facing downstream; weir 1 and weir 2 are stable; pool 1 is filled

Station 8+50 facing downstream; pool 2 is not visible (same depth); weir 3 is stable, but has gravel and leaves on top

Station 8+85 facing right bank and sill at station 9+00; pool downstream of driveway culvert is stable

Station 9+00 facing downstream; riffle grade control is stable

Station 9+25 facing downstream; material in channel likely causing minor left bank scour

Station 9+25 facing upstream; downstream tie-in of riffle grade control to existing stream bed slightly elevated

Station 9+75 facing downstream; about 40’ of no work area is degraded

Station 10+40 facing downstream; landscaping stakes present should be pounded into bank or removed and cut fabric; clay toe is stable

Station 11+90 facing downstream; sill top stones have scour visible on left bank

Station 12+00 facing right bank; scour downstream of sill

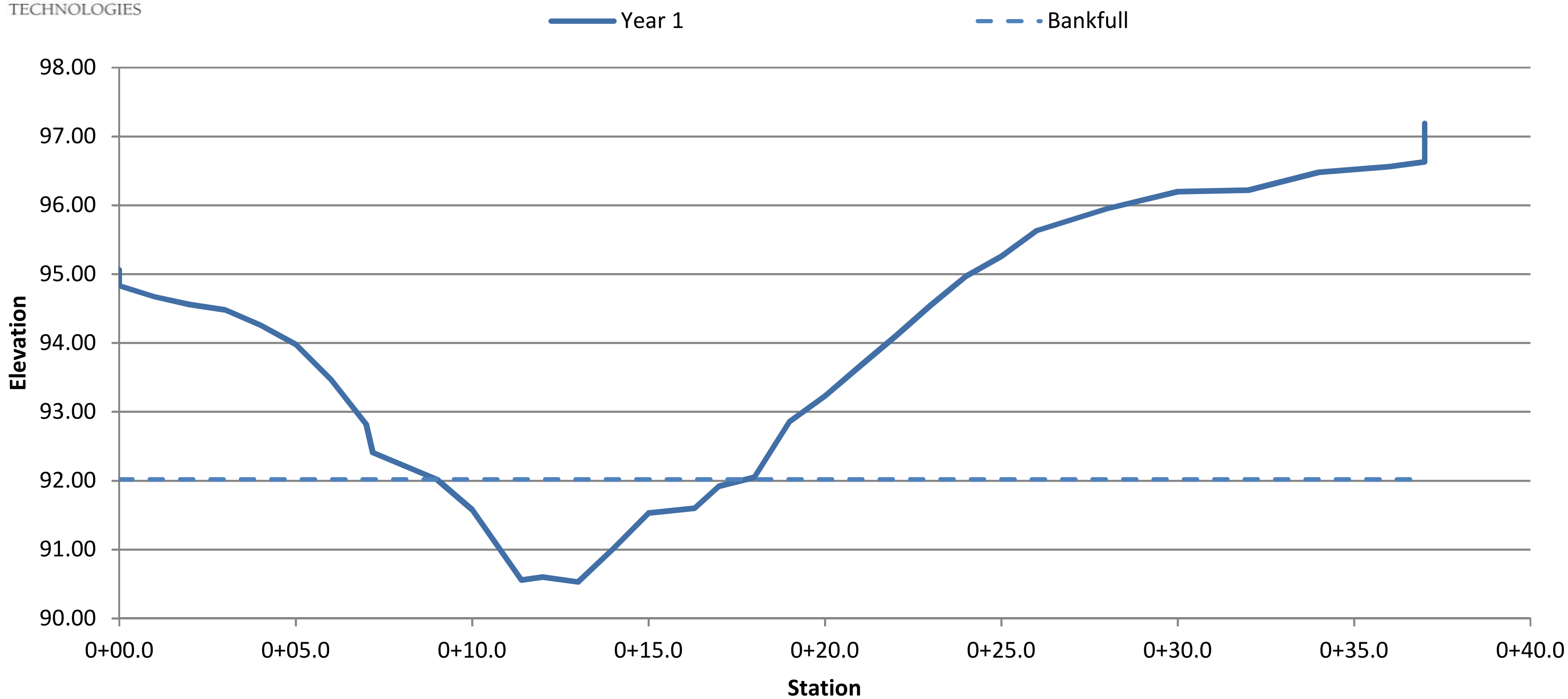
Station 12+00 facing left bank; scour downstream of sill

Station 12+15 facing upstream; scour downstream of sill on banks and bed

APPENDIX A-1

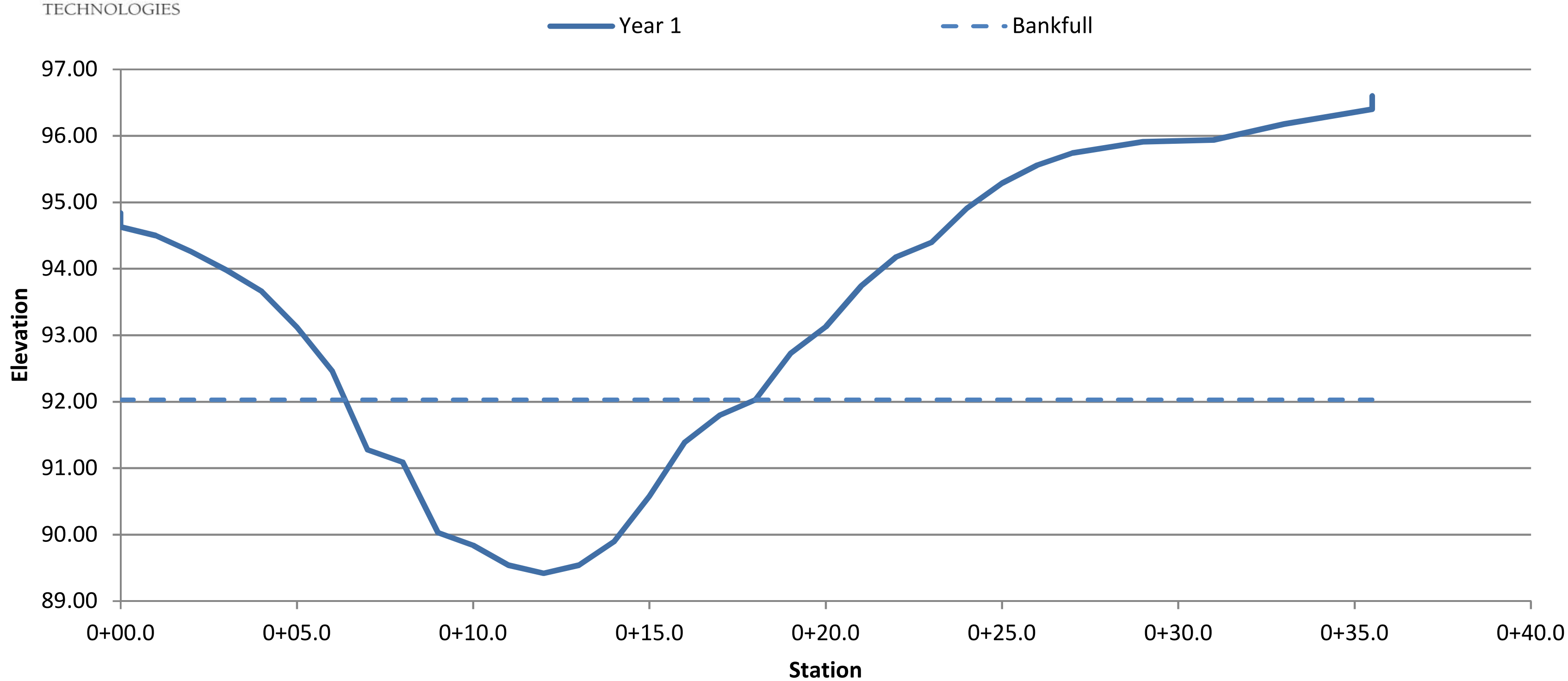
Vegetation Assessment Photographs

Cross Section 1



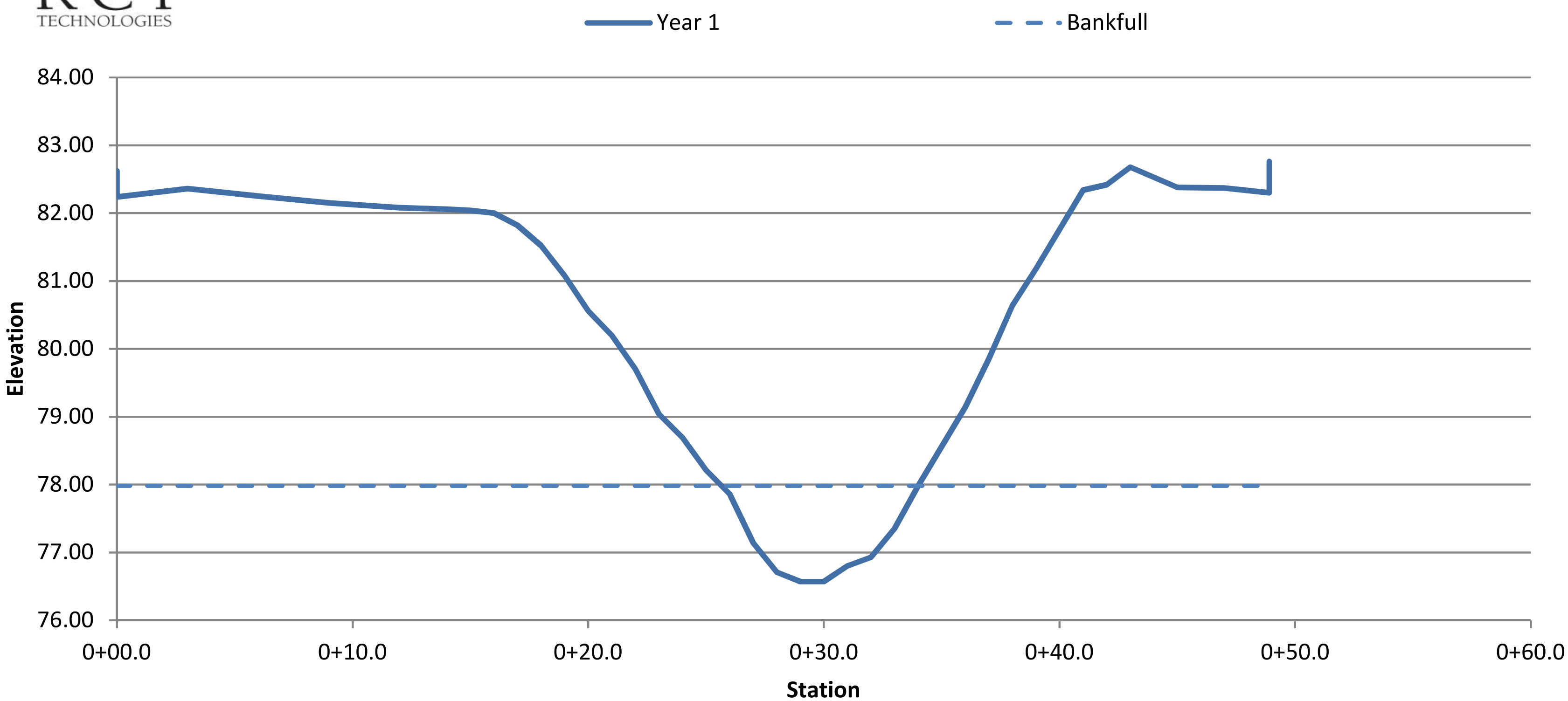
BKFL/TOB ELEV= 92.02	WIDTH (FT)	MEAN DEPTH (FT)	CROSS SECTION AREA (SQ FT)	WIDTH-DEPTH RATIO	DISCHARGE (cfs)
YEAR-1	8.8	0.8	6.7	11.5	40.1

Cross Section 2



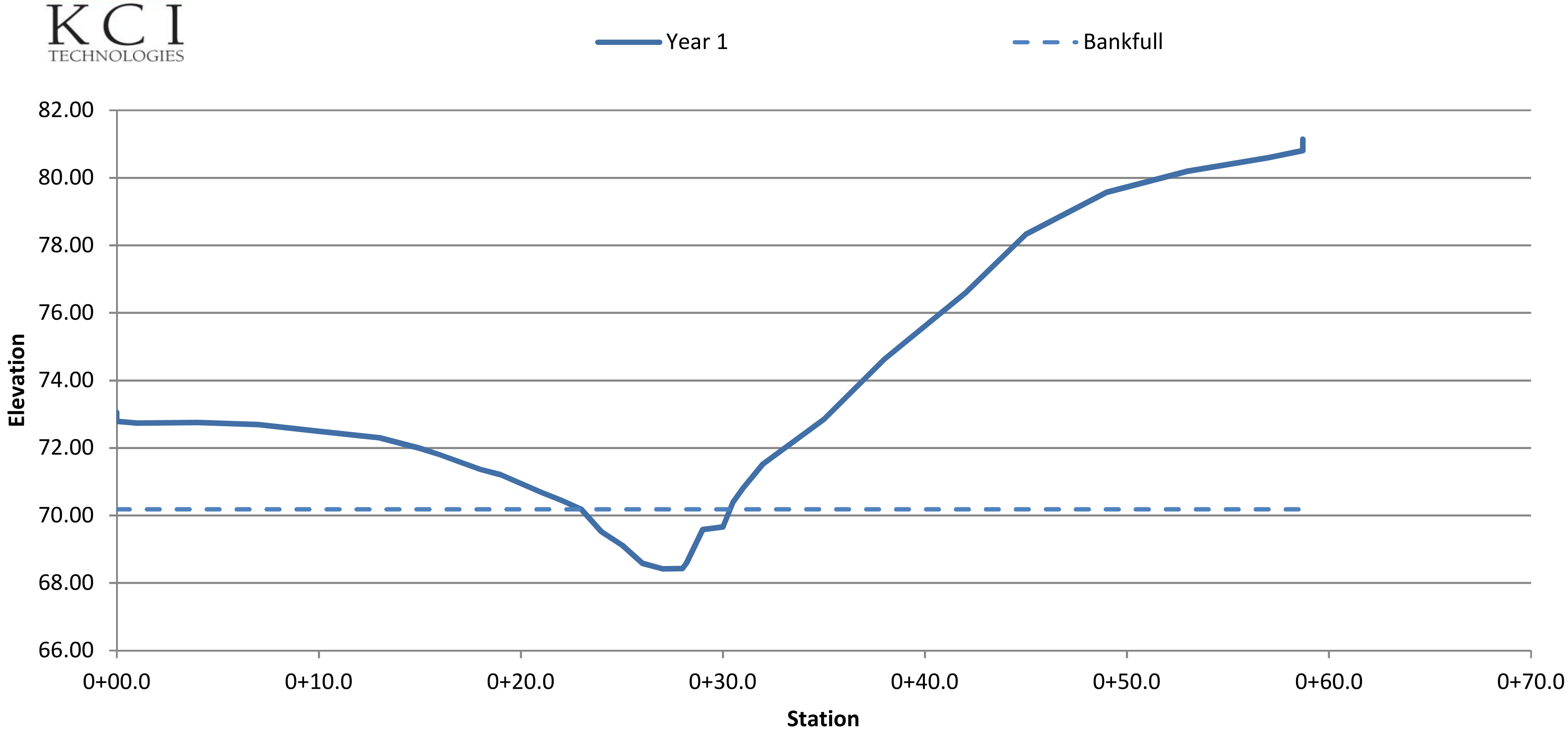
BKFL/TOB ELEV=	WIDTH (FT)	MEAN DEPTH (FT)	CROSS SECTION AREA (SQ FT)	WIDTH-DEPTH RATIO	DISCHARGE (cfs)
92.03					
YEAR-1	11.6	1.5	17.8	7.6	164.9

Cross Section 3



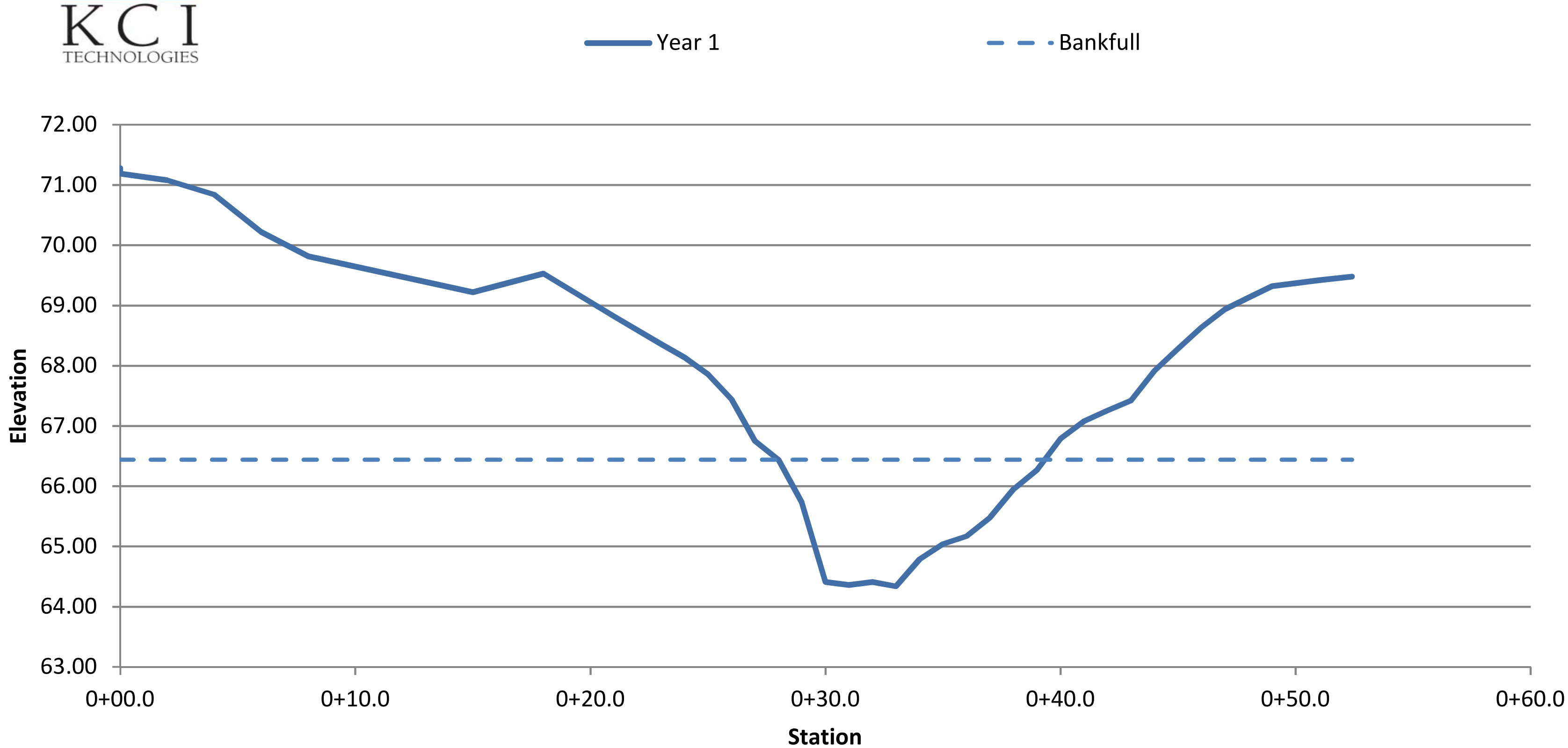
BKFL/TOB ELEV=	WIDTH (FT)	MEAN DEPTH (FT)	CROSS SECTION AREA (SQ FT)	WIDTH-DEPTH RATIO	DISCHARGE (cfs)
77.98					
YEAR-1	8.3	0.9	7.9	8.8	36.3

Cross Section 4



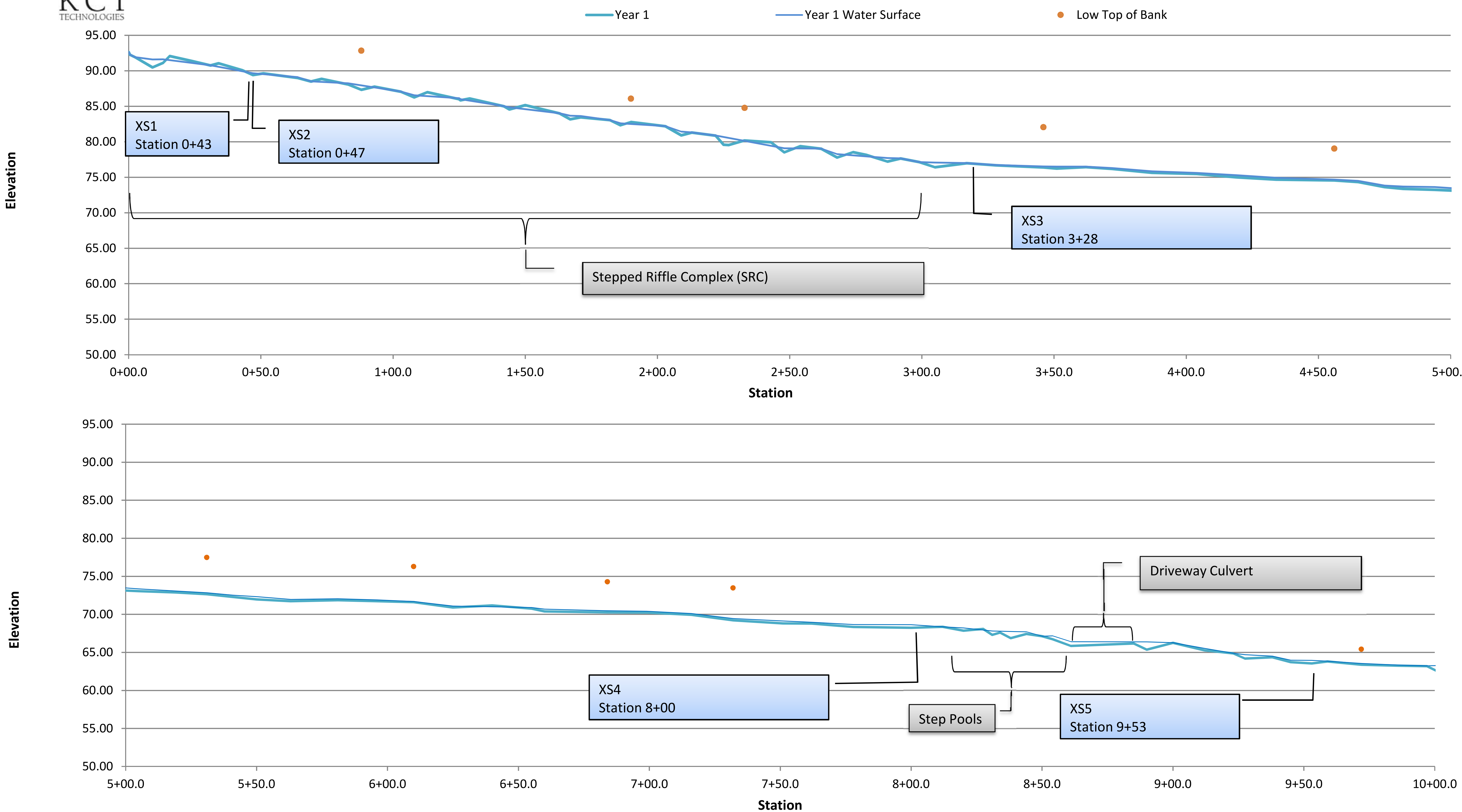
BKFL/TOB ELEV= 70.18	WIDTH (FT)	MEAN DEPTH (FT)	CROSS SECTION AREA (SQ FT)	WIDTH-DEPTH RATIO	DISCHARGE (cfs)
YEAR-1	7.4	1.1	7.8	6.9	37.1

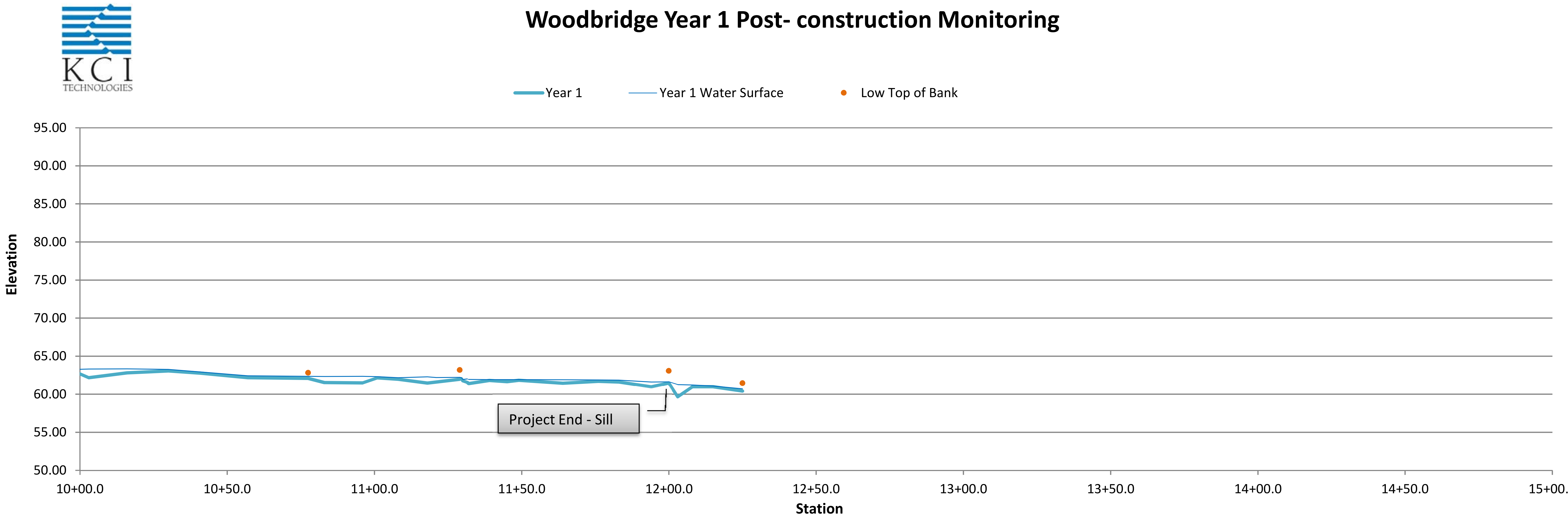
Cross Section 5



BKFL/TOB ELEV= 66.44	WIDTH (FT)	MEAN DEPTH (FT)	CROSS SECTION AREA (SQ FT)	WIDTH-DEPTH RATIO	DISCHARGE (cfs)
YEAR-1	11.3	1.3	14.8	8.6	79.7

Woodbridge Year 1 Post-construction Monitoring





KCI TECHNOLOGIES
Woodbridge Year 1 Post- construction Monitoring
Year 1
Year 1 Water Surface
Low Top of Bank
95.00
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
50.00
Elevation
Project End - Sill
10+00.0
10+50.0
11+00.0
11+50.0
12+00.0
12+50.0
13+00.0
13+50.0
14+00.0
14+50.0
15+00.0
Station

APPENDIX A-2

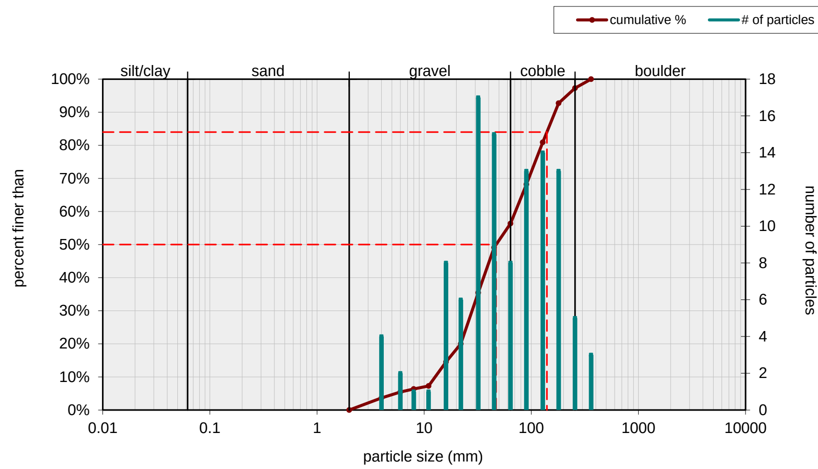
Geomorphic Assessment Photographs

Riffle Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	
very fine sand	0.062 - 0.125	
fine sand	0.125 - 0.25	
medium sand	0.25 - 0.5	
coarse sand	0.5 - 1	
very coarse sand	1 - 2	
very fine gravel	2 - 4	**4**
fine gravel	4 - 6	**2**
fine gravel	6 - 8	**1**
medium gravel	8 - 11	**1**
medium gravel	11 - 16	**8**
coarse gravel	16 - 22	**6**
coarse gravel	22 - 32	**17**
very coarse gravel	32 - 45	**15**
very coarse gravel	45 - 64	**8**
small cobble	64 - 90	**13**
medium cobble	90 - 128	**14**
large cobble	128 - 180	**13**
very large cobble	180 - 256	**5**
small boulder	256 - 362	**3**
small boulder	362 - 512	
medium boulder	512 - 1024	
large boulder	1024 - 2048	
very large boulder	2048 - 4096	
	total particle count:	110
bedrock	------------	
clay hardpan	------------	
detritus/wood	------------	
artificial	------------	
	total count:	110

Note: xs-3, riffle grade control

Riffle Surface Pebble Count, Woodbridge Year 1 Post-construction Monitoring



Size (mm)	
D16	17
D35	32
D50	47
D65	82
D84	140
D95	210

Size Distribution	
mean	48.8
dispersion	2.9
skewness	0.02

Type	
silt/clay	0%
sand	0%
gravel	56%
cobble	41%
boulder	3%

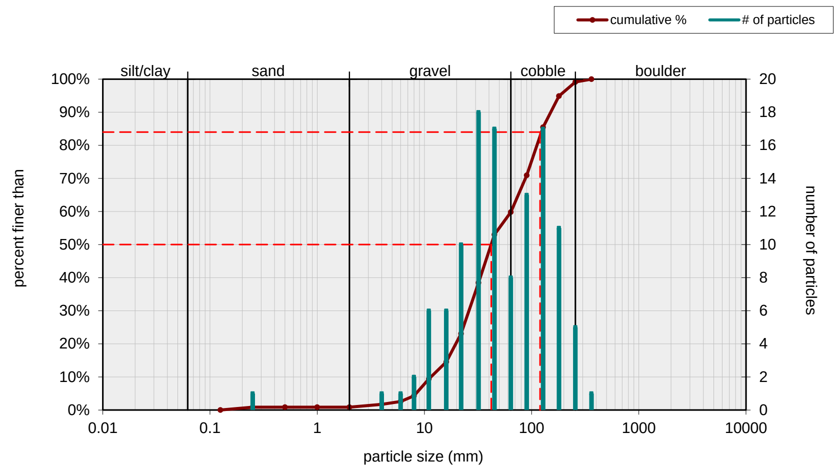
Riffle Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	
very fine sand	0.062 - 0.125	
fine sand	0.125 - 0.25	**1**
medium sand	0.25 - 0.5	
coarse sand	0.5 - 1	
very coarse sand	1 - 2	
very fine gravel	2 - 4	**1**
fine gravel	4 - 6	**1**
fine gravel	6 - 8	**2**
medium gravel	8 - 11	**6**
medium gravel	11 - 16	**6**
coarse gravel	16 - 22	**10**
coarse gravel	22 - 32	**18**
very coarse gravel	32 - 45	**17**
very coarse gravel	45 - 64	**8**
small cobble	64 - 90	**13**
medium cobble	90 - 128	**17**
large cobble	128 - 180	**11**
very large cobble	180 - 256	**5**
small boulder	256 - 362	**1**
small boulder	362 - 512	
medium boulder	512 - 1024	
large boulder	1024 - 2048	
very large boulder	2048 - 4096	
total particle count:		117

bedrock	------------	
clay hardpan	------------	
detritus/wood	------------	
artificial	------------	
total count:		117

Note: 6+88, channel bed material

Riffle Surface Pebble Count, Woodbridge Year 1 Post-construction Monitoring



Size (mm)	
D16	17
D35	29
D50	42
D65	75
D84	120
D95	180

Size Distribution	
mean	45.2
dispersion	2.7
skewness	0.03

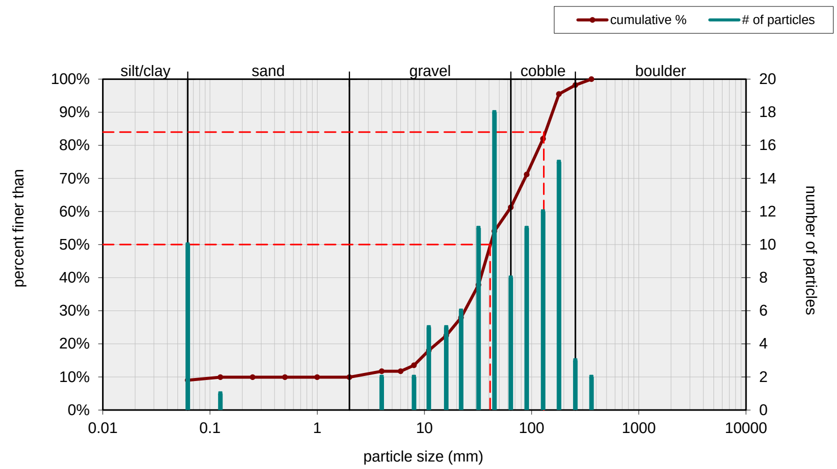
Type	
silt/clay	0%
sand	1%
gravel	59%
cobble	39%
boulder	1%

Riffle Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	**10**
very fine sand	0.062 - 0.125	**1**
fine sand	0.125 - 0.25	
medium sand	0.25 - 0.5	
coarse sand	0.5 - 1	
very coarse sand	1 - 2	
very fine gravel	2 - 4	**2**
fine gravel	4 - 6	
fine gravel	6 - 8	**2**
medium gravel	8 - 11	**5**
medium gravel	11 - 16	**5**
coarse gravel	16 - 22	**6**
coarse gravel	22 - 32	**11**
very coarse gravel	32 - 45	**18**
very coarse gravel	45 - 64	**8**
small cobble	64 - 90	**11**
medium cobble	90 - 128	**12**
large cobble	128 - 180	**15**
very large cobble	180 - 256	**3**
small boulder	256 - 362	**2**
small boulder	362 - 512	
medium boulder	512 - 1024	
large boulder	1024 - 2048	
very large boulder	2048 - 4096	
total particle count:		111
bedrock	------------	
clay hardpan	------------	
detritus/wood	------------	
artificial	------------	
total count:		111

Note: xs-5, channel bed material

Riffle Surface Pebble Count, Woodbridge Year 1 Post-construction Monitoring



Size (mm)	
D16	9.5
D35	29
D50	41
D65	73
D84	130
D95	180

Size Distribution	
mean	35.1
dispersion	3.7
skewness	-0.06

Type	
silt/clay	9%
sand	1%
gravel	51%
cobble	37%
boulder	2%

Designed Material Size Distributions

Riffle Grade Control

% Less Than	Size (mm)
10	20
30	76
50	112
60	152
84	198
100	224

Channel Bed Material

% Less Than	Size (mm)
16	10
30	25
50	41
85	140
100	178

APPENDIX A-3
Structure Assessment Photographs

Project Name: Woodbridge Post-Construction Biomonitoring
Project Number: 17134556.03 PHI_Coastal_Plain_v2_Wood.xlsx
Prepared by: CH Checked by: AJB Version: 1
Prepared date: 10/26/16 Checked date: 10/27/2016 Site Name:

KCI TECHNOLOGIES

		Raw Data											Scaled Metrics						Rating	
Site	Subshed Area (acres)	Instream Habitat	Epibenthic Substrate	Velocity Depth Diversity	Pool Glide Eddy Quality	Bank Stab (0-20)	Embeddedness	Percent Shading	Aesthetics (Trash)	Remoteness Score	# Woody Debris/ Rootwads	Max Depth	Instream Habitat	Epibenthic Substrate	Bank Stability	Shading	Remoteness	# Woody Debris/ Rootwads	PHI	PHI Rating
Wood US	35	2	3	6	6	20	20	30	11	2	0	37	55.40	50.48	100.00	31.57	12.14	81.46	55.18	Degraded
Wood DS	70	6	8	7	6	20	20	30	17	2	0	24	70.50	75.01	100.00	31.57	11.21	73.61	60.32	Degraded

Score	Narrative Rating
81-100	Minimally Degraded
66.0-80.9	Partially Degraded
51.0-65.9	Degraded
0-50.9	Severely Degraded

Project Name: Woodbridge Post-Construction Biomonitoring
Project Number: 17134556.03
Prepared by: CH
Prepared date: 10/26/16
Checked by: AJB
Checked date: 10/27/2016
PHI_Piedmont_v3_Ref.xlsx
Version: 2
Site Name:

		RAW DATA								SCALED METRICS								SCORES	
Site	Subshed Area (ac)*	Instream Habitat	Epibenthic Substrate	Embeddedness	Percent Shading	# Woody Debris/ Rootwads	Riffle Quality	Bank Stability	Remoteness Score	Instream Habitat	Epibenthic Substrate	Embeddedness	Percent Shading	# Woody Debris/ Rootwads	Riffle Quality	Bank Stability	Remoteness	PHI	PHI Rating
LWIN-108	411	15	15	20	85	2	16	2	9	87.47	82.35	88.89	77.04	16.67	100.00	12.77	54.03	64.9	Degraded

Score	Narrative Rating
81-100	Minimally Degraded
66.0-80.9	Partially Degraded
51.0-65.9	Degraded
0-50.9	Severely Degraded

Project Name: Woodbridge Post-Construction Biomonitoring
Project Number: 17134556.03
Prepared by: SL   Checked by: CH
Prepared date: 4/16/16   Checked date: 10/26/16

RBP_Woodbridge_High_Gradient_v1.xlsx
Version: 1
Site Name: Woodbridge

STATION ID	DATE	ESC	E	VD	SD	CF	CA	FR	BSL	BSR	VPL	VPR	RZL	RZR	TOTAL	PERCENT	CLASSIFICATION
Wood US	4/15/2016	5	15	6	17	16	0	13	10	10	4	5	1	2	104	52.00	Not Supporting
Wood DS	4/15/2016	6	16	7	13	15	0	12	10	10	5	5	8	8	115	57.50	Not Supporting

BSL - Bank Stability (left)
BSR - Bank Stability (right)
CA - Channel alteration
CF - Channel Flow Status
E - Embeddeddness
ESC - Epifaunal substrate / available co
FR - Frequency of riffles
RZL - Riparian Zone (left)
RZR - Riparian Zone (right)
SD - Sediment /deposition
VD - Velocity /depth
VPL - Vegetative Protection (left)
VPR - Vegetative Protection (right)
Total - Total Score

Total possible score = 200
Percent - Total/200*100

Classification Scoring	
>90%	Comparable to Reference
75.1-89.9%	Supporting
60.1-75.0%	Partially Supporting
<60%	Non-Supporting

APPENDIX A-4

Physical Habitat Assessment Photographs

Project Name: Woodbridge Year 1 Post-construction Monitoring
Project Number: 1713455603
Prepared by: CRH
Checked by: AJB
Prepared date: 10/20/2016
Checked date: 10/27/2016

BIBI_Coastal_Plain_v4_Woodbridge.xlsx
Version: 4
Site Name: WOOD US

Subphylum/ Class	Order	Family	Genus	Final ID	Note[1]	# of Org	FFG[2]	Habit[3]	Tolerance Value[4]
Insecta	Diptera	Chironomidae	Chaetocladius	Chaetocladius	I	10	Collector	sp	7
Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche	Cheumatopsyche	I	1	Filterer	cn	6.5
Crustacea	Copepoda	not identified	not identified	Copepoda	I	1	Collector	0	8
Insecta	Diptera	Chironomidae	Diamesa	Diamesa	P	1	Collector	sp	8.5
Insecta	Diptera	Chironomidae	Diplocladius	Diplocladius	I	10	Collector	sp	5.9
Oligochaeta	Haplotaxida	Enchytraeidae	not identified	Enchytraeidae	I	1	Collector	bu	9.1
Insecta	Diptera	Chironomidae	Eukiefferiella	Eukiefferiella	I	10	Collector	sp	6.1
Oligochaeta	Haplotaxida	Naididae	not identified	Naididae	I	73	Collector	bu	8.5
Insecta	Diptera	Chironomidae	Natarsia	Natarsia	I	1	Predator	sp	6.6
Insecta	Diptera	Chironomidae	Rheocricotopus	Rheocricotopus	I	5	Collector	sp	6.2
Insecta	Diptera	Simuliidae	Simulium	Simulium	I	3	Filterer	cn	5.7

1 Life Stage, I - Immature, P- Pupa, A - Adult, U - Undetermined; 2 Functional Feeding Group; 3 Primary habit or form of locomotion, includes bu - burrower, cn - clinger, cb - climber, sk - skater, sp - sprawler, sw - swimmer; 4 Tolerance Values, based on Hilsenhoff, modified for Maryland. An entry of "0" indicates information for the particular taxa was not available.

Project Name: Woodbridge Year 1 Post-construction Monitoring
Project Number: 1713455603
Prepared by: CRH Checked by: AJB
Prepared date: 10/20/2016 Checked date: 10/27/2016

BIBI_Coastal_Plain_v4_Woodbridge.xlsx
Version: 4
Site Name: WOOD DS

Subphylum/ Class	Order	Family	Genus	Final ID	Note[1]	# of Org	FFG[2]	Habit[3]	cb calc (HIDE ME!!)	Tolerance Value[4]
Oligochaeta	Haplotaxida	Naididae	not identified	Naididae	I	73	Collector	bu	0	8.5
Insecta	Diptera	Chironomidae	Chaetocladius	Chaetocladius	I	10	Collector	sp	0	7
Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche	Cheumatopsyche	I	3	Filterer	cn	0	6.5
Insecta	Diptera	Chironomidae	Diamesa	Diamesa	I	5	Collector	sp	0	8.5
Insecta	Diptera	Chironomidae	Eukiefferiella	Eukiefferiella	I	5	Collector	sp	0	6.1
Insecta	Diptera	Chironomidae	Eukiefferiella	Eukiefferiella	P	2	Collector	sp	0	6.1
Insecta	Trichoptera	Hydropsychidae	Hydropsyche	Hydropsyche	I	2	Filterer	cn	0	7.5
Insecta	Diptera	Chironomidae	Limnophyes	Limnophyes	I	5	Collector	sp	0	8.6
Gastropoda	Basommatophor	Lymnaeidae	Lymnaea	Lymnaea	I	1	Scraper	cb	cb	6.9
Insecta	Diptera	Chironomidae	Micropsectra	Micropsectra	I	3	Collector	cb, sp	cb	2.1
Insecta	Diptera	Chironomidae	not identified	Orthocladiinae	P	4	Collector	0	0	7.6
Insecta	Diptera	Chironomidae	Orthocladius	Orthocladius	I	10	Collector	sp, bu	0	9.2
Insecta	Diptera	Simuliidae	Simulium	Simulium	I	2	Filterer	cn	0	5.7

1 Life Stage, I - Immature, P- Pupa, A - Adult, U - Undetermined; 2 Functional Feeding Group; 3 Primary habit or form of locomotion, includes bu - burrower, cn - clinger, cb - climber, sk - skater, sp - sprawler, sw - swimmer; 4 Tolerance Values, based on Hilsenhoff, modified for Maryland. An entry of "0" indicates information for the particular taxa was not available.

Project Name: Woodbridge Year 1 Post-construction Monitoring
Project Number: 1713455603
Prepared by: CRH Checked by: AJB
Prepared date: 10/26/2016 Checked date: 10/27/2016

BIBI_Piedmont_v3_LWIN_108.xlsx
Version: 1
Site Name: LWIN_108

Subphylum/ Class	Order	Family	Genus	Final ID	Note[1]	# of Org	FFG[2]	Habit[3]	Tolerance Value[4]
Insecta	Diptera	Chironomidae	Ablabesmyia	ABLABESMYIA		1	Predator	sp	8.1
Insecta	Plecoptera	Nemouridae	Amphinemura	AMPHINEMURA		13	Shredder	sp, cn	3
Insecta	Coleoptera	Ptilodactylidae	Anchytarsus	ANCHYTARSUS		1	Shredder	cn	3.1
Insecta	Coleoptera	Elmidae	Ancyronyx	ANCYRONYX		1	Scraper	cn, sp	7.8
Insecta	Diptera	Chironomidae	Brillia	BRILLIA		3	Shredder	bu, sp	7.4
Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche	CHEUMATOPSYCHE		9	Filterer	cn	6.5
Insecta	Trichoptera	Philopotamidae	Chimarra	CHIMARRA		4	Filterer	cn	4.4
Insecta	Diptera	Chironomidae	Chironomini	CHIRONOMINI		2	0	0	5.9
Insecta	Diptera	Empididae	Clinocera	CLINOCERA		1	Predator	cn	7.4
Insecta	Diptera	Chironomidae	Diamesa	DIAMESA		1	Collector	sp	8.5
Insecta	Diptera	Chironomidae	not identified	DIAMESINAE		1	Collector	0	7.1
Insecta	Trichoptera	Hydropsychidae	Diplectrona	DIPLECTRONA		1	Filterer	cn	2.7
Insecta	Trichoptera	Philopotamidae	Dolophilodes	DOLOPHILODES		19	Filterer	cn	1.7
Insecta	Diptera	Chironomidae	Eukiefferiella	EUKIEFFERIELLA		1	Collector	sp	6.1
Insecta	Ephemeroptera	Ephemerellidae	Eurylophella	EURYLOPHELLA		1	Scraper	cn, sp	4.5
Gastropoda	Basommatophora	Ancylidae	Ferrissia	FERRISSIA		1	Scraper	cb	7
Insecta	Diptera	Chironomidae	Hydrobaenus	HYDROBAENUS		4	Scraper	sp	7.2
Insecta	Trichoptera	Hydropsychidae	Hydropsyche	HYDROPSYCHE		7	Filterer	cn	7.5
Insecta	Plecoptera	Leuctridae	not identified	LEUCTRIDAE		2	Shredder	sp, cn	0.8
Insecta	Coleoptera	Dytiscidae	Neoporus	NEOPOROUS		1	Predator	sw,cb	5
Insecta	Diptera	Chironomidae	not identified	ORTHOCLADIINAE		3	Collector	0	7.6
Insecta	Diptera	Chironomidae	Orthocladius	ORTHOCLADIUS		11	Collector	sp, bu	9.2
Insecta	Diptera	Chironomidae	Polypedilum	POLYPEDILUM		20	Shredder	cb, cn	6.3
Insecta	Diptera	Psychodidae	not identified	PSYCHODIDAE		1	0	0	4
Insecta	Diptera	Chironomidae	Rheocricotopus	RHEOCRICOTOPUS		1	Collector	sp	6.2
Insecta	Diptera	Simuliidae	Simulium	SIMULIUM		3	Filterer	cn	5.7
Gastropoda	Basommatophora	Lymnaeidae	Stagnicola	STAGNICOLA		1	Scraper	cb	7.8
Malacostra	Amphipoda	Crangonyctidae	Stygobromus	STYGOBROMUS		1	Collector	0	4
Insecta	Diptera	Chironomidae	not identified	TANYPODINAE		1	Predator	0	7.5
Insecta	Diptera	Chironomidae	not identified	TANYTARSINI		1	Collector	0	3.5
Insecta	Diptera	Chironomidae	Tanytarsus	TANYTARSUS		1	Filterer	cb, cn	4.9
Insecta	Diptera	Chironomidae	Thienemannimyia gro	THIENEMANNIMYIA GROUP		1	Predator	sp	8.2
Insecta	Diptera	Chironomidae	Tvetenia	TVETENIA		1	Collector	sp	5.1

1 Life Stage, I - Immature, P- Pupa, A - Adult, U - Undetermined; 2 Functional Feeding Group; 3 Primary habit or form of locomotion, includes bu - burrower, cn - clinger, cb - climber, sk - skater, sp - sprawler, sw - swimmer; 4 Tolerance Values, based on Hilsenhoff, modified for Maryland. An entry of "0" indicates information for the particular taxa was not available.

Scope of Work for Dembytown Monitoring

June 12, 2017

Ms. Michele G. Dobson
Harford County Department of Public Works
212 South Bond St, 1st Floor
Bel Air, MD 21014

RE: Scope of Work and Cost Proposal: Dembytown Stream Restoration Project Monitoring
Harford County Consultant Contract No. 16-073
Open-End Environmental Monitoring
KCI Job No. 161602035.01

Dear Ms. Dobson:

KCI Technologies, Inc. (KCI) is pleased to present our Scope of Work and Cost Proposal to perform five years of monitoring in and around the Dembytown stream restoration project on Foster Branch in Joppa, Harford County, Maryland. This proposal is based on the phone conversation on April 14, 2017, subsequent discussions, and the monitoring requirements laid out by the Baltimore District of the Army Corps of Engineers in a letter dated January 19, 2016. A detailed scope of work and fee derivation with man-hour breakdown are attached for your review. Our proposed fee for this work is **$54,411.82**.

Thank you for the opportunity to submit our Scope of Work. We look forward to working with you on this project. Should you have any questions about the enclosed material please do not hesitate to contact me.

Very truly yours,
KCI TECHNOLOGIES, INC.

James E. Deriu — *Direct Dial: (410) 316-7865*
Vice President – Natural Resources — *Email: james.deriu@kci.com*

Attachments

Dembytown Stream Restoration Monitoring

Scope of Work

Background

Harford County Department of Public Works recently completed a stream restoration project along a portion of Foster Branch in the vicinity of the Dembytown Road stream crossing. The Baltimore District, Army Corps of Engineers authorized the stream restoration under nationwide permit 2015-60430-M37 and is requiring monitoring as a condition of the permit. Information and data collected during the required monitoring activities will be used to assess various success criteria which will be used to evaluate the success of the Dembytown stream restoration project. The Army Corps of Engineers outlined the success criteria and years when monitoring activities should occur in the authorization letter sent to Harford County dated January 19, 2016. The required monitoring from the authorization letter is as follows:

Table 1 – Success Criteria for Stream Restoration

Level and Category	Parameter	Measurement	Success Criteria	Monitoring Years
1-Hydrology	Flow	Visual	Exceeds baseline (intermittent or perennial)	PC, 5
2-Hydraulics	Floodplain Connectivity	Bank height Ratio	<1.2	AB, 5
3-Geomorphology	Vertical Stability	Longpro/riffle crest elevations	<0.5 ft thalweg degradation from as-built	AB, 3
	Lateral Stability	BEHI	Moderate or Better	3
	Habitat Assessment	RBP-High Gradient	Greater than Baseline	PC, 3, 5
	Vegetative Cover	% cover	>80% cover in LOD	5
	Rosgen Stream Classification	X-section from riffle crests	Does not classify as G or F stream type	PC, 3, 5
4-Water Quality	NA	NA	NA	NA
5-Biology	Invasive Plant Reduction	% cover invasive species in LOD	Less than Baseline	PC, 5

Table 1 showing performance standards for stream restoration. AB=As-built, PC=Pre-construction, 1-5 corresponds to the monitoring year following construction, NA=Not applicable.

Table 2 – Success Criteria for Wetlands

Level and Category	Parameter	Measurement	Success Criteria	Monitoring Years
Hydrology	Hydrology indicators present	Delineation Form	Wetland Hydrology	5
Soil	Hydric Soils	Alpha-alpha dipyridyl test or hydric soils classification	Hydric soils present or positive reaction with Alpha-alpha dipyridyl	5
Vegetation	Hydrophytic	Delineation Form		5

Table 2 showing performance standards for restored and remediated wetlands. 1-5 corresponds to the monitoring year following construction, NA=Not applicable.

Harford County has requested a scope and fee for KCI to perform monitoring which fulfills the requirements placed on the Dembytown stream restoration project. Also, KCI will produce annual monitoring reports to the County which may be submitted to the Army Corps of Engineers to fulfill the annual reporting requirement.

Schedule

The anticipated schedule for completion of this Scope of Work is as follows:

Early-July 2017	Project kick-off meeting
Previous to Sept 30, 2017	Year 1 monitoring activities
November 15, 2017	Draft Year 1 Monitoring Report
December 15, 2017	Final Year 1 Monitoring Report
Previous to September 30, 2018	Year 2 monitoring activities
November 15, 2018	Draft Year 2 Monitoring Report
December 15, 2018	Final Year 2 Monitoring Report
Previous to September 30, 2019	Year 3 monitoring activities
November 15, 2019	Draft Year 3 Monitoring Report
December 15, 2019	Final Year 3 Monitoring Report
Previous to September 30, 2020	Year 4 monitoring activities
November 15, 2020	Draft Year 4 Monitoring Report
December 15, 2020	Final Year 4 Monitoring Report
Previous to September 30, 2021	Year 5 monitoring activities
November 15, 2021	Draft Year 5 Monitoring Report
December 15, 2021	Final Year 5 Monitoring Report

Project Tasks

Task 1: Project Initiation, Coordination

Subtask 1.1: Project Initiation

Within two weeks of receiving the Notice to Proceed, KCI Technologies, Inc. will hold a project kick-off meeting with the County Project Manager and designated County staff to discuss project coordination efforts and schedule of activities. The meeting will last no longer than two (2) hours. Results of the meeting will include a documented meeting summary.

Subtask 1.2: Project Coordination

Project coordination with County staff will be important throughout the course of the work effort. In addition to the project kick-off meeting described above, KCI proposes three meetings to coincide with the completion of substantial draft monitoring reports. Meetings will not be planned for the end of years 2 and 4 as those years have minimal monitoring occurring. These sessions will be necessary to ensure that project work and data collection results meet the County goals and objectives as well as the monitoring requirements set forth by the Army Corps of Engineers. The proposed milestone meetings are:

- At the completion of the Year 1 Monitoring Report (approx. Nov 15, 2017),
- At the completion of the Year 3 Monitoring Report (approx. Nov 15, 2019),
- At the completion of the Year 5 Monitoring Report (approx. Nov 15, 2021).

KCI will prepare an agenda and e-mail it to the Project Manager for input two days prior to the milestone meeting date. Additionally, KCI will prepare meeting minutes to be reviewed first by the County Project Manager, and then distributed by KCI to appropriate Harford County DPW staff.

KCI's project manager will maintain communication with the County's Project Manager, prepare and submit monthly invoices with progress reports, and schedule and direct the performance of the work. The monthly progress reports will be short, bulleted documents providing status updates on the monitoring efforts described above. Such reports will include summaries of any technical problems or issues associated with the monitoring efforts, any interesting or unusual conditions observed in the field, and will document actions planned for the upcoming month. KCI's project manager will be responsible for timely submission of all deliverables for this work effort.

Task 1 Deliverables

- KCI will prepare meeting agendas and meeting minutes for all coordination meetings for the duration of the project.

Task 2: Monitoring

KCI will perform monitoring in and around the Dembytown stream restoration project that fulfills the monitoring requirements as outlined in the Baltimore District, Army Corps of Engineers letter received January 19, 2016.

Invasive Plant and Vegetation Assessments

KCI proposes an annual visual inspection and assessment of the project LOD for the presence of invasive plant species. The Army Corps of Engineers monitoring requirements only specify that this invasive plant inspection be performed in year 5. Performing this inspection annually allows the County to respond quickly to remove any invasive species observed in the project LOD. Waiting until year 5 allows the potential for invasive plants to overrun the project area, making removal at that point more difficult and costly.

The annual invasive plant assessment will document the presence of any invasive plant species within the project LOD and estimate the percent cover of any observed invasive plant species. Photographs will be taken to document the vegetative composition of the site during each annual inspection. Observations made during the current inspection will be compared to previous monitoring data in order to document any changes in coverage of invasive plant species within the project LOD. If invasive plants are observed, KCI will immediately notify Harford County DPW of the species observed the estimated percent coverage. This scope does not cover the development of an invasive species eradication and maintenance plan if annual site visits document their presence. The development of an eradication and maintenance plan would be performed under a separate task order.

During year 5 a final visual inspection of the riparian buffer plantings along the restored channel will be completed to assess the re-establishment and viability of the riparian buffer plantings per the intent of the design. If identified, specific problem areas will be noted on the landscape plans and KCI will document evidence of invasive species, infestation, disease, browsing, mortality, and/or establishment of volunteer species that may have contributed to the problem. This vegetative assessment will produce an estimate of the percent cover of vegetation within the LOD, providing the information needed to assess the success criteria for vegetative cover.

Geomorphology Assessments

KCI will perform geomorphic monitoring in the Dembytown project area. KCI proposes geomorphic monitoring in years 1, 3, and 5. The Army Corps of Engineers monitoring requirements specify that this geomorphological monitoring be performed at the as-built stage, and in years 3 and 5. In KCI's experience, as-built monitoring frequently does not have the level of detail required to assess change over time in vertical and lateral stability of restoration projects. During year 1, KCI will establish permanent monuments on each bank at each cross-section, and also at the top and bottom of the longitudinal profile. These monuments will be used as benchmarks to compare elevations of the cross-sections and profile across years. Standard stream surveying techniques will be used to survey permanently monumented cross-sections and a longitudinal profile at the Dembytown restoration reach.

The longitudinal profile of the restoration reach will be surveyed along the thalweg thread and include riffles, pools, water surface, and (where discernable) bankfull and terrace features. Longitudinal profile surveys are completed to determine riffle/pool sequencing patterns and to determine any changes in channel slope and the extent of any degradation or aggradation that may occur in subsequent surveys. The vertical location of the monumented cross-sections will be tied into the surveyed profile. Photographs will be taken along to profile to document site conditions.

Two cross-section surveys, each located on a riffle, will be completed within the restoration project reach. Each cross-section will be surveyed with a laser level and stadia rod. The cross-sections will include survey of the floodplain, monuments, and all pertinent channel features including:

- Top of bank
- Bankfull elevation
- Edge of water
- Limits of point and instream depositional features
- Thalweg
- Floodprone elevation

Four photographs of each cross-section will be taken; looking upstream at the cross-section, looking downstream at the cross-section, looking from the right bank to the left bank, and looking from the left bank to the right bank.

Data from geomorphic assessments will also be used to determine the stream type for each reach as categorized by the Rosgen Stream Classification methodology (Rosgen, 1996). In this classification methodology, streams are categorized based on their measured field values of entrenchment ratio, width/depth ratio, sinuosity, water surface slope, and channel materials. The Rosgen Stream Classification categorizes streams into broad stream types, which include the following:

Table 3 – Rosgen Channel Classifications

Channel Type	General Description
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.
A	Steep, entrenched, confined, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.
B	Moderately entrenched, moderate gradient, riffle dominated channel with infrequently spaced pools. Moderate width/depth ratio. Narrow, gently sloping valleys. Very stable plan and profile. Stable banks.
C	Low gradient, meandering, slightly entrenched, point-bar, riffle/pool, alluvial channels with broad, well-defined floodplains.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks. Active lateral adjustment, high bedload and bank erosion.
DA	Anastomosing (multiple channels) narrow and deep with extensive, well-vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable streambanks.
E	Low gradient, Highly sinuous, riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander/width ratio.
F	Entrenched, meandering riffle/pool channel on low gradients with high width/depth ratio and high bank erosion rates.
G	Entrenched “gully” step/pool and low width/depth ratio on moderate gradients. Narrow valleys. Unstable, with grade control problems and high bank erosion rates.
Source: Rosgen, 1996.	

The resulting classification will be used as one measure of success of the restoration (see Table 1).

A visual assessment of lateral stability will be performed using Rosgen’s Bank Erosion Hazard Index (BEHI; Rosgen 2001). The BEHI compiles information about the ratio of bank height to bankful height, root depth, root density, surface cover, and angle of the bank along with adjustments made for bank material type and stratification of bank material (see Table 4).

Table 4 – Bank Erosion Hazard Index, metrics scores and values

	Bank Erosion Hazard Index Values						
		Very Low (1.0 - 1.9)	Low (2.0-3.9)	Moderate (4.0 - 5.9)	High (6.0 -7.9)	Very High (8.0 -9.0)	Extreme (10)
Erosion Metrics	Ratio of Bank Height to Bankful Height	1.0 - 1.10	1.11 - 1.19	1.2 - 1.59	1.6 - 2.09	2.1 - 2.8	>2.8
	Root Depth	1.0 - 0.9	0.89 - 0.50	0.49 - 0.30	0.29 - 0.15	0.14 - 0.05	<0.05
	Root Density	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
	Surface Protection	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
	Bank Angle	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119

The BEHI assessment will be used as one measure of success of the project (see Table 1).

Physical Habitat Assessment

The Dembytown restoration site will be visually-assessed based on physical characteristics and various habitat parameters following the Environmental Protection Agency's Rapid Bioassessment Protocol (RBP) habitat assessment for high gradient streams (Barbour et. al, 1999). Physical habitat assessments will be performed during the geomorphology assessment visits during years 3 and 5.

The RBP habitat assessment consists of a review of ten biologically significant habitat parameters that assess a stream's ability to support an acceptable level of biological health. Each parameter is given a numerical score from 0-20 (20=best, 0=worst), or 0-10 (10=best, 0=worst) for individual bank parameters, and a categorical rating of optimal, suboptimal, marginal or poor. Overall habitat quality typically increases as the total score for each site increases. The RBP parameters assessed for high gradient streams are as follows.

RBP High Gradient Parameters

Epifaunal substrate/available cover	Channel alteration
Embeddedness	Frequency of riffles/bends
Velocity/depth regime	Bank stability
Sediment deposition	Vegetative protection
Channel flow status	Riparian vegetative zone width

Stream physical habitat data will be used to assess success of the project when compared against habitat scores from before construction (see Table 1).

Hydrology Visual Assessment

During year 5 KCI will perform a visual assessment of flow and determine if the stream throughout the Dembytown restoration project is intermittent or perennial. The visual assessment will take place duringthe same visit as the invasive plant and vegetative assessment in July of year 5. This will allow the hydrology to be assessed during the natural low-flow period. This assessment will be compared to preconstruction conditions to measure the success criteria for hydrology. Hydrological conditions will be photodocumented at the time of the assessment. This assessment of hydrology will be used to assess the success of the project when compared against the preconstruction hydrological condition of the site (see Table 1). Visual assessments of hydrology will also be performed during other monitoring activities throughout the five years of monitoring. These additional assessments may prove useful if year 5 falls during a drought year, where the required assessment of hydrology may not reflect the actual hydrological conditions during an average year.

Wetland Assessment

Before the end of year 5, KCI will conduct a site investigation to identify waters of the United States (WUS) and jurisdictional wetlands within the study area in accordance with the “Routine” method outlined in the U.S. Army Corps of Engineers (USACE) Wetland Delineation Manual (Environmental Laboratory, 1987) and the Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Atlantic and Gulf Coastal Plain Region (Environmental Laboratory, 2010). Wetland and WUS boundaries will be marked with flagging tape. A GPS will be used to capture the locations of placed flags and markers. A field map will be developed illustrating wetlands and waterway(s) locations and associated flag numbers. Total acres of existing wetlands will be calculated and can be used to document that the project offset any wetlands lost during project construction. The wetlands assessment will be used to assess three success criteria for the restoration project (see Table 2).

Task 3: Data Entry and Analysis

Field data and observations will be managed, and analyzed using appropriate scientific methodology.

Subtask 3.1: Invasive Plant and Vegetation Data

Invasive plant data will be entered into spreadsheets which will contain any species observed and the percent cover of the site.

Subtask 3.2: Geomorphic Data

The stream cross-section, and longitudinal profile data will be partially analyzed using the Ohio Department of Natural Resources Reference Reach Spreadsheet Version 4.3L (Mecklenburg, 2006). A Rosgen Level II classification will be assigned to each cross-section reach. The following values and ratios will be calculated, compared to previous monitoring, and included in the report.

Sinuosity	Entrenchment ratio	Bankfull cross-section area
Slope	Bankfull height	Velocity
Floodprone width	Bankfull width	Discharge
Width / depth ratio	Mean depth	Sheer stress

BEHI data will be entered into a spreadsheet which calculates the overall score and assigns a narrative rating to the assessed bank.

BEHI Condition Ratings

BEHI Total Score	Narrative Rating
≤ 7.25	Very Low
7.26 – 14.75	Low
14.76 – 24.75	Moderate
24.76 – 34.75	High
34.76 – 42.50	Very High
42.51 - 50	Extreme

These data will be used detect changes in channel geometry and channel materials distribution over time in this restoration reach. Special emphasis will be placed on vertical and lateral stability.

Subtask 3.3: Physical Habitat Data

Physical habitat data will be entered into an Excel spreadsheet. The 10 individual RBP habitat parameters are summed to obtain an overall RBP assessment score. The total score, with a maximum possible score of 200, is then placed into one of four narrative categories based on their percent comparability to reference conditions (Plafkin et al., 1989).

RBP Physical Habitat Condition Ratings

RBP Score	Narrative Rating
>151	Comparable to Reference
126 – 150	Supporting
101 – 125	Partially Supporting
<100	Non-supporting

Subtask 3.4: Wetland Assessment Data

Wetland assessment data will be recorded on data sheets and digitally using GPS-enabled tablets or hand held GPS units. Data will be entered into standard spreadsheets and GIS databases and or shapefiles. GIS data will be used to produce maps of the wetland delineation for use in the year 5 report.

Task 4: Reporting

KCI will prepare an annual monitoring technical memorandum for monitoring activities completed each year of this scope of work. This technical memorandum may serve as the County's annual monitoring report to the Army Corps of Engineers. A draft technical memo will be emailed to the Harford County DPW Project Manager by November 15th of each monitoring year. Comments will be incorporated into a final technical memo and delivered to Harford County DPW on or before December 15th of each monitoring year.

Annual Monitoring Technical Memo – Year 1 will cover monitoring activities from the summer of 2017 and will contain the results of geomorphology and invasive plant monitoring. Annual Monitoring Technical Memo – Year 2 will cover monitoring activities from 2018 and will contain the results of annual invasive plant assessment. Annual Monitoring Technical Memo – Year 3 will cover monitoring activities from 2019 and include monitoring results for geomorphology, physical habitat, and invasive plant assessments. The year 3 tech memo will compare geomorphology results between years 1 and 3. Annual Monitoring Technical Memo – Year 4 will cover monitoring activities from 2020 and will contain the results of annual invasive plant assessment. Annual Monitoring Technical Memo – Year 5 will cover monitoring activities from 2021 and include monitoring results for geomorphology, physical habitat, invasive plant, and wetland assessments. The year 5 tech memo will compare geomorphology results from preconstruction, the as-built survey, years 1, 3, and 5 where appropriate. The year 5 memo will also compare the physical habitat assessments from preconstruction, year 3, and year 5. This memo will final project assessment of vegetative cover and identify any invasive plant species located within the project LOD. This memo will also include the results of the hydrology visual assessment and compare those results to the preconstruction condition. The year 5 memo will also compile the wetlands information gathered in the field into a Natural Resources Inventory section that can be utilized for waterway permitting requirements as described below. The description of wetland/stream systems within the project area will include information required by USACE, as specified in their most recent guidance documents and jurisdictional determination checklists at the time of the investigation. Information to be included in the report may include results of the delineation, field data sheets of wetland systems, representative photographs of site conditions and a NRI Map with surveyed wetland boundaries overlain. Data sheets and site photographs will be appended to the text.

Task 5 Deliverables

- Draft Annual Monitoring Technical Memorandum; Years 1, 2, 3, 4, and 5 (digital copy for review)
- Final Annual Monitoring Technical Memorandum; Years 1, 2, 3, 4, and 5 (digital copy)
- Excel Spreadsheets containing all invasive plant, geomorphic, habitat assessment, and wetland assessment raw data, calculations, and results.

References:

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water; Washington D.C.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C. EPA 440-4-89-001.

Rosgen, D.L. 2001. A Practical Method of Computing Streambank Erosion Rate. Proceedings of the 7th Federal Interagency Sedimentation Conference, Vol. 2, pp. 9-15, March 25, 2001, Reno, NV. Available on the Wildland Hydrology website at: http://www.wildlandhydrology.com/html/references_.html

Rosgen D. 1996. Applied Fluvial Morphology. Wildland Hydrology. Pagosa Springs, CO.

Harford County Open-End Environmental Monitoring

TASK 1 - Dembytown Monitoring - Years 1 through 5
June 12, 2017

		KCI							
Task	**Task Description**	**Principal**	**PM**	**Environmental Engineer**	**Water Quality Biologist**	**Aquatic Ecologist**	**Wetland Scientist**	**KCI Hours**	**Fee**
1	**Project Initiation and Coordination**								
1.1	Project Initiation and Kick-off Meeting		8			3		11	$ 1,603.78
	Progress Meetings (3 total, years 1, 3, and 5)		12			9		21	$ 2,936.94
1.2	General Coordination		40			20		60	$ 8,609.20
	subtotal hours	*0*	*60*	*0*	*0*	*32*	*0*	*92*	**$ 13,149.92**
	subtotal labor	*$ -*	*$ 9,372.00*	*$ -*	*$ -*	*$ 3,777.92*	*$ -*		
2	**Monitoring**								
2.1	**Year 1**								
	Invasive Plant Assessment				8			8	$ 690.24
	Geomorph			20	22			42	$ 4,536.56
	subtotal hours	*0*	*0*	*20*	*30*	*0*	*0*	*50*	**$ 5,226.80**
	subtotal labor	*$ -*	*$ -*	*$ 2,638.40*	*$ 2,588.40*	*$ -*	*$ -*		
2.2	**Year 2**								
	Invasive Plant Assessment				8			8	$ 690.24
	subtotal hours	*0*	*0*	*0*	*8*	*0*	*0*	*8*	**$ 690.24**
	subtotal labor	*$ -*	*$ -*	*$ -*	*$ 690.24*	*$ -*	*$ -*		
2.3	**Year 3**								
	Invasive Plant Assessment				8			8	$ 690.24
	Geomorph			16	20			36	$ 3,836.32
	Habitat Assessment					2		2	$ 236.12
	subtotal hours	*0*	*0*	*16*	*28*	*2*	*0*	*46*	**$ 4,762.68**
	subtotal labor	*$ -*	*$ -*	*$ 2,110.72*	*$ 2,415.84*	*$ 236.12*	*$ -*		
2.4	**Year 4**								
	Invasive Plant Assessment				8			8	$ 690.24
	subtotal hours	*0*	*0*	*0*	*8*	*0*	*0*	*8*	**$ 690.24**
	subtotal labor	*$ -*	*$ -*	*$ -*	*$ 690.24*	*$ -*	*$ -*		
2.3	**Year 5**								
	Invasive Plant and Vegetative Cover Assessment				8			8	$ 690.24
	Geomorph			16	16			32	$ 3,491.20
	Habitat Assessment					2		2	$ 236.12
	Hydrology Visual Assessment				2			2	$ 172.56
	Wetland Assessment						20	20	$ 1,903.40
	subtotal hours	*0*	*0*	*16*	*26*	*2*	*20*	*64*	**$ 6,493.52**
	subtotal labor	*$ -*	*$ -*	*$ 2,110.72*	*$ 2,243.28*	*$ 236.12*	*$ 1,903.40*		
3	**Data Entry and Analysis**								
3.1	**Invasive Plant (years 1-5)**				10			10	$ 862.80
3.2	**Geomorphic (years 1, 3, 5)**			2	12			14	$ 1,299.20
3.3	**Habitat Assessment (year 3 and 5)**					2		2	$ 236.12
3.4	**Wetland Assessment (year 5)**				4		16	20	$ 1,867.84
	subtotal hours	*0*	*0*	*2*	*26*	*2*	*16*	*46*	**$ 4,265.96**
	subtotal labor	*$ -*	*$ -*	*$ 263.84*	*$ 2,243.28*	*$ 236.12*	*$ 1,522.72*		
4	**Task Report**								
4.1	**Year 1**								
	Draft Report		2	4	16	8		30	$ 3,165.04
	Final Report		1	2	2	2		7	$ 828.72
	subtotal hours	*0*	*3*	*6*	*18*	*10*	*0*	*37*	**$ 3,993.76**
	subtotal labor	*$ -*	*$ 468.60*	*$ 791.52*	*$ 1,553.04*	*$ 1,180.60*	*$ -*		
4.2	**Year 2**								
	Draft Report		2		4			6	$ 657.52
	Final Report		1		1			2	$ 242.48
	subtotal hours	*0*	*3*	*0*	*5*	*0*	*0*	*8*	**$ 900.00**
	subtotal labor	*$ -*	*$ 468.60*	*$ -*	*$ 431.40*	*$ -*	*$ -*		
4.3	**Year 3**								
	Draft Report		2	4	16	8		30	$ 3,165.04
	Final Report		1	2	2	2		7	$ 828.72
	subtotal hours	*0*	*3*	*6*	*18*	*10*	*0*	*37*	**$ 3,993.76**
	subtotal labor	*$ -*	*$ 468.60*	*$ 791.52*	*$ 1,553.04*	*$ 1,180.60*	*$ -*		
4.4	**Year 4**								
	Draft Report		2		4			6	$ 657.52
	Final Report		1		1			2	$ 242.48
	subtotal hours	*0*	*3*	*0*	*5*	*0*	*0*	*8*	**$ 900.00**
	subtotal labor	*$ -*	*$ 468.60*	*$ -*	*$ 431.40*	*$ -*	*$ -*		
4.5	**Year 5**								
	Draft Report		2	4	24	8	32	70	$ 6,900.72
	Final Report		1	2	4	2	8	17	$ 1,762.64
	subtotal hours	*0*	*3*	*6*	*28*	*10*	*40*	*87*	**$ 8,663.36**
	subtotal labor	*$ -*	*$ 468.60*	*$ 791.52*	*$ 2,415.84*	*$ 1,180.60*	*$ 3,806.80*		
	Subtotal Task - Hours	0	75	72	200	68	76	491	
	Hourly Rate	$168.89	$156.20	$131.92	86.28	$118.06	$95.17		
	Labor Subtotal	$0.00	$11,715.00	$9,498.24	$17,256.00	$8,028.08	$7,232.92		$ 53,730.24
	Summary								
	KCI Labor Fee								$ 53,730.24
	KCI Direct Expenses								$ 681.58
	TOTAL								**$ 54,411.82**

Harford County Open-End Environmental Monitoring

TASK 1 - Dembytown Monitoring - Years 1 through 5
June 12, 2017

Description	Number	Type	Unit Cost	Extended Cost
Sediment Sampling				
Misc Equipment	1	lump sum	$200.00	$200.00
Travel				
Mileage (12 trips at 52 miles, 4 trips at 46 miles)	808	miles	$0.535	$432.28
Field maps	10	color 11X17 copies	$0.98	$9.80
Draft and Final Report		digital submission		
Misc copies/prints	300	bw 8.5x11 copies	$0.05	$15.00
	10	color 11X17 copies	$0.98	$9.80
	30	color 8.5x11copies	$0.49	$14.70
			TOTAL	$681.58

Watershed Restoration Plans

Attachment 2
Maryland Department of the Environment Science Services Administration (MDE-SSA) Comments on the Harford County Stormwater Waste Load Allocation (WLA) Implementation Plan: Sediment and the Chesapeake Bay TMDL

Overall Harford County's SW-WLA Implementation Plans for the Chesapeake Bay TMDLs and for the Bynum Run sediment TMDL are of good quality. The plans include all required elements and employ a variety of restoration projects, including new structural stormwater management facilities to treat impervious surface, retrofits to existing stormwater management facilities, stream restoration, tree planting, and forest buffers. MDE-SSA commends the County for developing implementation plans addressing the SW-WLAs for each Chesapeake Bay segment-shed TMDL, rather than an implementation plan for the entire County. Additionally, MDE-SSA commends the County on the following aspects of its plans:

- The County provides a thorough and detailed assessment, which includes prioritization of all current potential restoration projects in various County watersheds.
- The County includes sand filters and infiltration as two options for converting current dry detention facilities, rather than relying solely on standard wet pond conversion. While conversion of dry detention facilities to wet ponds provides additional water quality benefits for some pollutants, conversion to a sand filter or infiltration basin can provide even greater downstream water quality benefits; such as moderating temperature.
- A good example of the type of adaptive management these plans should utilize is the Bynum Run Sediment TMDL plan. The County discusses how some of the high and medium priority projects could be replaced for a lower priority project, if the high and medium projects are eventually deemed not feasible due to various concerns.
- The County indicated street sweeping will not be a strategy to meet nutrient or sediment TMDL goals. This seems reasonable, since street sweeping is an expensive program to maintain, particularly with respect to fine sediment and nutrient removal, and does not provide any volumetric reduction of stormwater runoff.
- The County plans to revisit its BayFAST modeling in 2017 and 2019 to assess the impact of implemented projects and new development, per updated land-use and impervious cover data it will have obtained. MDE-SSA recommends that the impacts of restoration projects and new development on pollutant loads be tracked separately from one another.
- The County plans to implement many new monitoring programs, including a biological monitoring program that will use MBSS protocols and be submitted to MD DNR for approval prior to implementation. The County also plans to monitor channel geometry downstream of planned restoration projects. These types of monitoring programs are an excellent plan for assessing progress towards SW-WLAs.

In this memo, MDE's Science Services Administration is providing "Major Comments" that address significant points or shortcomings with this plan, as well as "Specific Comments". Responses to both major and specific comments must be addressed in the next annual report submission.

Major Comments

Chesapeake Bay TMDL:

The County takes credit for natural, existing forest buffers by estimating the acres of current, natural stream buffers, using a 150-foot buffer width. The County estimates that there are currently 4,200 acres of existing forest buffers in the Bush River, which reduces 60,500 lbs of TN and 2,100 lbs of TP. While this is an informative assessment, and it is true that these natural, existing buffers are providing water quality benefits by treating upstream drainage areas, the County cannot credit these existing buffers against the required reductions, since they were in place during the Bay TMDLs' baseline conditions. Therefore, the effects of these buffers were accounted for in the Chesapeake Bay TMDL baseline loads. This issue should be immediately addressed, and reflected in the County's plan.

Within one year of EPA approval, the County will also need to develop SW-WLA implementation plans for three recently-approved TMDLs, the Bush River and Gunpowder River PCB TMDLs as well as the Swan Creek Sediment TMDL.

Attachment 2
Harford County Stormwater WLA Implementation Plan
MDE-SSA Comments

Nutrient and Sediment Plans:

General Comments

Comment Type	Location	Comment
1. General Sediment and Nutrients	Harford County, Bynum Run Sediment Plans and Chesapeake Bay Nutrient Plans	**MDE recommends that the County remove loads from new development in assessing progress towards the SW-WLA reductions. The Chesapeake Bay nutrient SW-WLA plans follow the same modeling procedures.** The County does not separately account for growth, but does factor in growth when modeling its 2015 progress scenario. The County calculates its target load from a 2007 progress scenario. The County then models a 2015 progress scenario, including loads from new development. Because the County includes loads from new development in the progress scenario, the required load reduction increases, since the loads from new development are greater than any restoration BMPs implemented between 2007-2015.
2. General Sediment and Nutrients	Harford County, Bynum Run Sediment Plans and Chesapeake Bay Nutrient Plans	**While the County provides the total load reduction from the suite of BMPs in the planned implementation scenario, it would be helpful to see more specific information to better understand which specific practices yield the majority of the planned load reductions.** The County provides detailed tables of the BMPs and acres treated for each BMP type, in the baseline, progress, and planned implementation scenarios. It would be helpful if the County provided load reductions per BMP type, in addition to the acres treated per type of SWM BMP. MDE recommends that the County provide estimates of reductions per BMP type. While BayFAST/MAST do not output a load reduction per BMP type, it could be done in a simple spreadsheet using back-calculated loading rates from a BayFAST/MAST No Action scenario and the applicable BMP efficiencies. The County could report this information using the template spreadsheet made available on the TMDL Data Center entitled “Optional Worksheet for MS4 SW-WLA Implementation Planning”.

3. General Sediment and Nutrients	Harford County, Bynum Run Sediment Plans and Chesapeake Bay Nutrient Plans	**For the Chesapeake Bay nutrient plans, the County used MAST. The County could have used BayFAST to do its Chesapeake Bay TMDL modeling as well.** In the Bynum Run Sediment TMDL implementation plan, the County used BayFAST to model the baseline, progress, and planned implementation sediment loads. This allowed the County to reset the BMP implementation level in its baseline and progress scenarios, as well as the land-use data. This meant the County could use its impervious surface data to model its baseline and progress scenario loads. The MAST 2010 No Action scenario indicates that there are only 7,803 acres of impervious surface in the Bush River. County impervious surface data indicates that there are at least 13,887 acres of impervious surface. If the County used BayFAST for its Chesapeake Bay TMDL nutrient plans, this may have resulted in a more accurate accounting of baseline, progress, and planned implementation loads.
4. General Sediment	Harford County, Bynum Run Sediment Plans	**The County should clarify why dry detention structures were included SW WLA plans.** The County indicates that SWM BMPs constructed prior to 2002 were not included in their baseline scenario, since these facilities provide little to no water quality treatment, and they do not meet current SWM regulations. However, the County includes dry detention structures built after 2002 in its baseline scenario load estimates. These facilities have a significant drainage area, especially in comparison to other SWM facilities included in the scenario. Even if they were constructed post-2002 due to being grandfathered in, for consistency purposes, they are providing the same amount of water quality treatment as a dry detention structure built prior to 2002.

5. General Sediment	Harford County, Bynum Run Sediment Plans	**The County should make the necessary editorial correction in its next revision of the Bynum Run Sediment TMDL plan. The County references the statement in the TMDL, which says "Theoretically extending these permitting requirements to all urban stormwater sources."** The County subsequently discusses how Section 1B of their permit correctly defines the permit area. The County seems to have misinterpreted the statement in the TMDL. The statement is indicative of a theoretical situation whereby other NPDES stormwater dischargers in the watershed, i.e., industrial stormwater facilities, would have the same retrofit requirements applied as a Phase I MS4 permit. Since the time of the TMDL, the industrial stormwater permit, as well as other NPDES stormwater permits, have incorporated restoration/retrofit requirements.
6. General Sediment	Harford County, Bynum Run Sediment Plans, p. ES-2	**Editorial Change** On page ES-2 of the Bynum Run sediment TMDL plan, the County says the TMDL requires a 19% reduction from all urban areas in the watershed, excluding the Town of Bel Air. This is not correct. The tech memo to the TMDL indicates that a 20% reduction is applied to jurisdictional Phase II MS4s in the watershed.
7. General Sediment	Harford County, Bynum Run Sediment Plans, p. ES-3	**Editorial Change** On page ES-3 of the Bynum Run sediment TMDL plan, the County indicates that it will achieve a 20% reduction in sediment loads by the end of the current permit cycle. This should read 20% of the required reduction will be achieved at the end of the permit cycle, or an overall 3% reduction in sediment loads. The 2015 baseline load is 1,222 ton/yr of sediment. The target load is 972 ton/yr of sediment, which represents a 250 ton/yr reduction from 2015 conditions. Table ES-2 inidicates that a 40 ton/yr reduction by 2019 (16% of 250 ton/yr and 3% of 1,222).
8. General Sediment	Harford County, Bynum Run Sediment Plans, p. ES-4	**Editorial Change** On page ES-4 of the Bynum Run sediment TMDL plan, the County says that it reserves the right to participate in any authorized trading program. While this is true as it relates to the Chesapeake Bay TMDLs, Maryland's draft trading program does not apply to meeting local, State TMDL loading targets.

9. General Sediment and Nutrients	Harford County, Bynum Run Sediment Plans, p. 2-9, and Chesapeake Bay Nutrient Plans	**Editorial Change** Page 2-9 of the Bynum Run Sediment TMDL implementation plan indicates that Maryland Department of Planning land-use data was used to develop the TMDL. This is not correct. The TMDL was developed using the Chesapeake Bay Phase 5.2 Watershed model. The County should make the necessary editorial correction in its next revision of the plan. Similarly, the Chesapeake Bay TMDL nutrient plans indicate that MAST was developed using MDP land-use data. This is not correct. MAST uses the Chesapeake Bay Phase 5.3.2 watershed model land-use.
10. General Sediment	Harford County, Bynum Run Sediment Plans	**To be consistent with the TMDL and reduction percentage (urban only), the County should only apply the reduction percentage to the urban land-use loads.** The County includes forest loads in its baseline load estimates in the Bynum Run Sediment TMDL implementation plan. Further, the County calculates the target load/reduction by applying the TMDL SW-WLA required percent reduction to the summation of the modeled urban and forest loads. There is no need to include forest loads in the analysis.
11. General Sediment and Nutrients	Harford County, Chesapeake Bay Nutrient and Sediment Plan	**Editorial Change - Consistency** The County Phase I MS4 Impervious Area (Updated Baseline Condition for Bush River) in Table 2-6 should equal that listed in Table 2-4 (5,773 impervious acres). Instead, acres in Table 2-6 are 5,770 impervious acres. Same problem with Gunpowder River. County Phase I MS4 Impervious area in the updated current condition scenario is 1,140 in Table 6-8 but 1,440 in Table 6-10. If the impervious area changes in table 6-10, there will need to be a revision to the nutrients and sediment calculated as part of the current condition, unless those calculations were conducted with the acreage from table 6-8.
12. General Sediment and Nutrients	Harford County, Bynum Run Sediment Plans and Chesapeake Bay Nutrient Plans	**Future Changes to BMP nutrient reduction credits** Future calculations for tree planting nutrient reduction credits will need to be revised in the next iteration of implementation plans due to the recent urban tree canopy expert panel findings and report.

Chesapeake Bay TMDLs and Phase III WIP

By August 2018 MDE is responsible for submitting a draft Phase III Chesapeake Bay Watershed Implementation Plan (WIP) to the U.S. Environmental Protection Agency (EPA). MDE will coordinate the development of Maryland's Phase III WIP with Harford County and other MS4 jurisdictions based on several key principles:

- **Phase III WIP Development:** Current MS4 permit conditions and restoration work are consistent with the Bay's TMDLs and shall be used to help inform the development of the Phase III WIP. For example, information documented in MS4 restoration plans and financial assurance plans will be the basis for WIP III development and future permit conditions. Multiple permit cycles will be needed to achieve the ultimate nutrient reduction targets, which, for Harford County, is expected to extend beyond 2025.
- **WIP III Coordination:** The timeline below provides Harford County and the Phase I MS4 permit community with two opportunities for providing input, in addition to the public review process.
  - **May 2017** Initial Guidance and Q&A Session
  - **Sept. 2017** Draft implementation information from local partners
  - **Dec. 2017** State feedback to local partners if necessary
  - **April 2018** Final implementation information from local partners
  - **Aug. 2018** Draft Phase III WIP due to EPA

Scope of Work Bush River TMDL Restoration Plan

EA Engineering, Science, and Technology, Inc., PBC

225 Schilling Circle, Suite 400
Hunt Valley, MD 21031
Telephone: 410-584-7000
Fax: 410-771-1625
www.eaest.com

29 June 2017

Mrs. Christine Buckley
Harford County Government
Department of Public Works
220 South Main Street
Bel Air, Maryland 21014

RE: Bush River PCB TMDL Study - Open-End Environmental Monitoring Contract – No. 16-073
Submitted via E-Mail: cmbuckley@harfordcountymd.gov, mgdobson@harfordcountymd.gov

Dear Mrs. Buckley:

EA Engineering, Science, and Technology, Inc., PBC (EA) is pleased to submit this Scope of Work (SOW) and Cost Estimate to the Harford County Department of Public Works (the County) to develop a generalized technical approach for attaining the Bush River total maximum daily load (TMDL) stormwater waste load allocation (WLA) for polychlorinated biphenyls (PCBs). The County plans to integrate the proposed technical approach into the PCBs restoration plan program for the Bush River.

Introduction

According to the approved TMDL for the Bush River by the Environmental Protection Agency (EPA), "NPDES regulated stormwater allocations to the Bush River will be expressed as single, aggregate WLAs. Upon approval of the TMDL, "NPDES-regulated municipal stormwater and small construction stormwater discharges effluent limits should be expressed as Best Management Practices (BMPs) or other similar requirements, rather than as numeric effluent limits"."

The PCB baseline loads for nonpoint sources is calculated to be 65.8 percent and 34.2 percent for point sources and the required percent load reduction to stormwater for PCBs in the Bush River watershed in the County is 62 percent. Nonpoint sources of PCBs in the Bush River watershed include direct atmospheric deposition to the river, runoff from non-regulated watershed areas, one contaminated site (MD 446 Union Road Dump), and tidal influence from the Chesapeake Bay mainstem. Point sources include National Pollutant Discharge Elimination System (NPDES) regulated stormwater runoff within the watershed and two NPDES permitted municipal wastewater treatment plants. The NPDES regulated stormwater total PCBs baseline loads of the Bush River watershed is estimated at 49.7 g/year.

The proposed SOW, project schedule, assumptions, and deliverables are as follows:

Task 1 – Project Initiation and Progress Meetings

EA will conduct a project kick-off meeting upon receipt of a formal NTP from the County. The meeting will involve all key project personnel and will include a detailed discussion of the lines of communication for the project, review of the proposed technical approach to the SOW, coordination efforts necessary for the project, a timeline of scheduled activities, and project deliverables. EA will coordinate with the County to obtain relevant data prior to the kick-off meeting. EA will attend three progress meetings to discuss project status, help coordinate changes or updates, address unforeseen problems, and keep the project on track.

Assumptions:

- In addition to the kick-off meeting, EA has assumed three additional progress meetings during the course of this project.
- All meetings will be held at the County's offices.

Deliverables:

- EA will develop draft and final meetings minutes for each progress meeting.
- EA will provide Monthly Progress Reports including a detailed invoice.

Task 2 – Data Collection

- Desktop Assessment: EA will use the geographical coordinates and available GIS for all the list of NPDES regulated stormwater permits within the Bush River watershed identified in the TMDL document that could potentially convey PCB loads to the river, regulated industrial facilities, industrial land use, identified contaminated sites, and high density urban areas. EA will also obtain available GIS layers for the Bush River watershed from the County: storm drain system & outfalls; land use; existing structural and nonstructural BMPs; monitoring locations; industrial/commercial sources, and associated drainage areas.
- Past Watershed Studies/Assessments: EA will review data sources relative to the MS4 permit and TMDL requirements for the Bush River watershed provided by the County. EA will provide a short technical memorandum summarizing the data received and any information data gaps.
- Field Assessment: A two person field crew of will spend up to 2 days in the field performing windshield surveys within the Bush River watershed of locations identified in the previous step. That information will be used to develop a list of priority areas that will receive a detailed field assessment in Task 3.

Task 3 – Analysis

EA will perform basic calculations to identify potential project candidates, and support the ranking and 10% design concepts for the top projects in Task 4.

- Baseline and Existing Conditions Modeling: EA will perform modeling on baseline and existing conditions.
  - Quantify preliminary pollutant load reduction targets and schedules to meet applicable stormwater WLAs, based on MDE information
  - Quantify post-baseline BMP reductions
- Proposed Scenario Modeling:
  - Develop screening process to identify and prioritize cost-effective structural and nonstructural water quality improvement projects
  - BMP load reductions will be estimated using the MDE approved reduction efficiencies for structural BMPs
- Technical Memorandum: EA will develop a technical memorandum describing the results of the desktop and field assessments, and recommendations for implementing additional urban stormwater BMPs as an approach to reducing PCB loads to the Bush River watershed. EA will also suggest potential BMPs along with a planning level cost-benefit analysis. A brief narrative description of the estimated PCB load reduction that could potentially be achieved, and will note the general type, size and location of each BMP being considered. EA will provide one draft and final technical memorandum to the County for comments, a revised draft-final, and a revised technical memorandum.

Task 4 – Project Alternatives (10% Design)

EA will rank the proposed projects based on estimated PCB reductions and planning level and costs.

- Scoring and Prioritizing: EA will develop sets of ranking and scoring criteria, making use of ranking systems in past watershed improvement studies, offer an initial suggested ranking system, and revise it per County comments. This will include estimates of anticipated pollutant removal amounts (PCBs), and planning level costs (design, permitting, and construction).
- 10% Concepts: Top project candidates will be presented to the County for comment, and a maximum of 10 projects will have simplified (10%) design concept sheets developed, along with a Technical Memorandum that provides a summary of the process, and a narrative of each project.

Task 5 – Final Recommendations and Report

- GIS Database: EA will develop GIS layer of the proposed BMPs for the Bush River watershed.
- Report: Individual Fact Sheets will be developed for a maximum of 10 projects identified in Task 4. Additional details regarding their design, permitting, cost, and maintenance will be expanded on, including: a location map of each project site, an 8.5x11-inch design concept showing the potential improvements, a description of major design features with general dimensions, permitting needs, land acquisition needs, and estimated pollutant removal. Appendices will be provided for detailed calculations (e.g., pollutant removal, cost estimates). EA will provide one draft and final report to the County for comments, a revised draft-final, and a revised final report.

Project Schedule

EA is providing the following tentative project schedule for the above-defined project tasks. A more detailed schedule will be provided based on EA's receipt of NTP and execution of any contract documents from the County.

Table 1. Proposed Project Schedule

Task	Period of Performance
NTP	0
Task 1 – Project Initiation, and Progress Meetings	Within 2 weeks of NTP
Task 2 – Data Collection	Within 3 weeks of NTP
Task 3 – Analysis	TBD
Task 4 – Project Alternatives (10% Design)	TBD
Task 5 – Final Recommendations and Reporting	TBD

Cost Estimate

To complete all of the above described work, EA will provide the services to the County on a Time and Materials basis with a **Not-to-Exceed budget** of **$42,520.02**. All invoicing for this work will be submitted on a monthly basis with a progress report, and will be supported with timesheet backups that indicate employee classifications, employee numbers, and their hourly rates. A breakdown of the staff types, hours and labor costs to be used for this project is provided below:

Table 2. Cost Estimate

Staff Classification	Hours	Hourly Rate	Total Cost
Principal	10	$199.05	$1,990.50
Project Manager	60	$125.94	$7,556.40
Environmental Engineer	80	$101.62	$8,129.60
Natural Resources Biologist	70	$60.06	$4,204.20
Environmental Scientist	70	59.77	$4,183.90
CADD/GIS Technician	194	$76.23	$14,788.62
Clerical	20	$69.67	$1,393.40
Total Labor Hours	504	**Total Labor Cost**	$42,246.62
		Other Direct Costs	$273.40
		Total Project Cost	$42,520.02

Thank you for the opportunity to provide the County with the above SOW and cost estimate. We look forward to working with the County. If you have any questions about this proposal, please feel free to call myself or Mike Powell at 410-584-7000.

Sincerely,

Sanita Corum

Sanita Corum
Project Manager
EA Engineering, Science, and Technology, Inc., PBC

cc: Michele Dobson – Harford County DPW
Mr. Jeff Boltz – EA
Mr. Mike Powell – EA

Scope of Work Swan Creek Sediment TMDL Restoration Plan

AECOM

April 17, 2017

Ms. Christine Buckley
Harford County Department of Public Works
15 North Bond Street
Bel Air, Maryland 21014

Subject: Proposal for Swan Creek Restoration Plan TMDL for Sediment

Dear Ms. Buckley:

AECOM is pleased to submit this proposal to develop a Restoration Plan that addresses the Total Maximum Daily Load (TMDL) Stormwater Waste Load Allocation (WLA) for the Swan Creek watershed for sediment impairment and to meet the Harford County's National Pollutant Discharge Elimination (NPDES) Municipal Separate Storm Sewer System (MS4) permit requirements. Our lump sum fee for this work is $54,957. Attached with this letter are:

- Scope of work
- Labor-hours and cost to perform the work

AECOM looks forward to working with you on this project. Please contact me at 301.820.3000 or our proposed project manager for this project, Melissa Bernardo Hess, PE at 301.820.3463 if you have any questions regarding this proposal.

Sincerely,

Michael Proctor, PE
Associate Vice President

Attachments

Harford County
Swan Creek Restoration Plan for Sediment
Scope of Work

Background

Harford County's (County) National Pollutant Discharge Elimination System (NPDES) Municipal Storm Separate Sewer System (MS4) Permit (Part IV.E.2) requires the County to develop and implement restoration plans that addresses each Total Maximum Daily Load (TMDL) Stormwater Waste Load Allocation (WLA) in the County. In general, TMDLs are issued by the Maryland Department of Environment (MDE) and approved by the Environmental Protection Agency (EPA). The restoration plans are required to be developed and submitted to MDE for approval as a part of the County's NPDES MS4 Annual Report. Once approved by MDE, these restoration plans are enforceable under the County's NPDES MS4 Permit. A TMDL for sediment impairment was approved for Swan Creek by MDE on September 30th, 2016. Swan Creek also has a TMDL for nutrients, and the Restoration Plan was developed by AECOM in January 2016. The objective of this scope of services is to assist the County in developing a restoration plan that addresses the TMDL for sediment impairment in the Swan Creek watershed.

The Swan Creek watershed has a drainage area of approximately 15,523 acres. Approximately 11,116 of those acres are in the MS4 regulated area. According to MDE's TMDL document for Swan Creek, urban stormwater runoff is identified as the major contributor of sediment loads. The primary goals of the restoration plan is to assess baseline pollutant loads; develop target load reductions considering the restoration measures implemented by the County after the TMDL baseline year (2010 for Swan Creek sediment TMDL); identify restoration projects that will protect high-quality waters and reduce existing and future sediment loads. The County's NPDES MS4 Permit requires the following items to be included in the restoration plan.

- Final dates for meeting the WLAs and a detailed schedule for implementing TMDL restoration strategies including structural, non-structural and alternative stormwater management projects, and programmatic and operational controls
- Cost estimates for the proposed restoration strategies
- Mechanism for evaluating and tracking the implementation of restoration plans
- Recommendation of an ongoing, iterative process such as monitoring or modeling to document progress towards meeting the stormwater WLAs

This proposed scope of work has been developed following the County's NPDES MS4 Permit requirements for developing a restoration plan for TMDL WLAs and MDE's document "Guidance for Developing Stormwater Wasteload Allocation Implementation Plans for Nutrient and Sediment Total Maximum Daily Loads" (November, 2014). Additionally, Restoration Plans developed by AECOM (URS) for Harford County for Swan Creek and Bynum Run for nutrient and sediment impairments respectively will be used as references for the development of this Restoration Plan.

Scope of Work

1. Data Collection, Review and Identification of Sources

Swan Creek Watershed is a subwatershed of the Northern Chesapeake Bay Tidal Fresh Basin (CB1TF). Based on the analysis conducted by AECOM for the development of Restoration Plan for nutrients impairment for Swan Creek, the contributing drainage area of the entire watershed is approximately 15,523 acres. The MS4 regulated area, or the area for which Harford is responsible for managing, is approximately 11,116 acres (71.6% of the total watershed area).

As a part of this task, AECOM will obtain and review the existing information from MDE TMDL documents for Swan Creek. AECOM will also obtain any additional applicable reports from the County and review them. Applicable geographic information system (GIS) data related to the watershed such as land use, impervious area, and location of stormwater Best Management Practices (BMPs) will be used. Point and non-point sources of sediment loads will be identified using the collected data. AECOM reviewed the watershed conditions of Swan Creek as a part of development of Restoration Plan for nutrients; we will compare the current GIS data sets to the previously done watershed assessment to identify any changes in land use conditions as well as existing stormwater management facilities.

2. Determination of Baseline Loads and Target Loads

As a part of developing the restoration plans for the Swan Creek TMDL, it is required that water quality modeling be conducted to determine the baseline loads for the TMDL year (i.e. 2010). The baseline model will also include estimation of load reductions achieved due to the implementation of BMPs in the watershed since 2010.

MDE guidance recommends using the Maryland Assessment Scenario Tool (MAST) or Chesapeake Bay Facility Assessment Scenario Tool (BayFAST) to determine the sediment baseline loading. This project will use the BayFAST model, as selected by the County. County land use data will be used as input in the model. The existing BMPs implemented prior to the TMDL baseline year will be included in the model to determine the baseline loads.

Another modeling scenario will be developed to determine the restoration plan target loads. This scenario will determine the potential sediment load reductions that are achieved from the BMPs implemented since the TMDL baseline year. The modeling scenarios will be compared to obtain the new target load reduction percentage for the Swan Creek TMDL. The BMP information for the modeling scenarios will be obtained from the County and from BMP efficiencies published in MDE document "Accounting for Stormwater Wasteload Allocation and Impervious Acres Treated" (August, 2014).

3. Determination of Restoration Strategies to Meet the TMDL goals

AECOM will use MDE guidance document "Accounting for Stormwater Wasteload Allocation and Impervious Acres Treated" (August, 2014) and County data such as the Phase II Watershed Implementation Plan (WIP II), capital improvement program (CIP), and applicable stream assessment reports to identify structural, non-structural and alternative urban stormwater restoration strategies to meet the TMDL goals. The restoration strategies recommended as part of

Swan Creek's nutrient TMDL Restoration Plan will also be reviewed to determine their applicability in reducing sediment loads. AECOM will also conduct a desktop analysis to identify additional restoration strategies in the Swan Creek watershed that are not included in the above-mentioned County data. Programmatic and operational practices that focus on reducing the sediment loads will also be recommended as a part of the proposed restoration strategies. The identified restoration strategies will be included in the proposed conditions model to estimate the potential load reductions from each type of restoration practices. Implementation costs for each proposed strategy will be obtained from the County's CIP, University of Maryland Center for Environmental Sciences (UMCES) publication "Cost of Stormwater Management Practices in Maryland Counties" (2011), BayFAST, or from other local experience. A prioritization ranking will be developed based on the load reduction and implementation costs for each restoration strategy to identify the high priority restoration strategies to be included in the implementation schedule.

Development of Restoration Plan

A draft restoration plan for Swan Creek that summarizes the analyses conducted and modeling processes, along with GIS figures of the watershed, tables of summary data and documentation of coordination with the County, will be submitted to the County for review. The draft plan will be developed by referencing and incorporating some elements of the previously developed Restoration Plans for Swan Creek and Bynum Run, which have been approved by the County. The draft restoration plan will also include:

- Proposed dates for meeting applicable WLAs and a planning-level schedule for implementing the structural, non-structural and alternative urban stormwater restoration projects. Per discussions with Harford County staff, site-specific BMP implementation will not be included at this time, but the plan will provide general recommendations related to the number of BMPs needed to reach the TMDL goals and or/ general locations for management programmatic and operational restoration measures (e.g. street sweeping, inlet cleaning etc.).
- Planning level costs for plan implementation. Potential funding sources will be identified, including grants and other available funds. Recommendations will also be made regarding fee structure, implementation, etc.
- Recommended methods/procedures for evaluating and tracking the implementation of restoration plans through monitoring or modeling to document progress toward meeting established benchmarks, deadlines, and stormwater WLAs.

AECOM will submit digital copies of the draft restoration plan to Harford County for review. Based on comments from the County, AECOM will make revisions and provide 3 hard copies and one digital copy of the final restoration plan.

Meetings

AECOM will attend a kickoff meeting with Harford County and other stakeholders to identify the primary drivers for developing the restoration plan. Meetings or conference calls would be scheduled at 50% and 75% completion of the project to track progress. In addition conference calls will be held to discuss the project progress as needed.

Schedule

Per the NPDES MS4 requirements, the County is required to submit the Restoration Plan to MDE as a part of its NPDES MS4 Annual Report i.e. June, 2018. AECOM anticipates receiving Notice to Proceed no later than April 30th 2017 to complete the development of the draft Restoration Plan by August, 2017 and final Restoration Plan by September, 2017.

Cost

The AECOM fee estimate to provide the above services is provided on the attached sheet.

Assumptions and Exclusions

This Scope of Work for the Swan Creek Restoration Plan does not include the following items:

- Preparing individual site plans or conceptual designs.
- Preparing detailed cost estimates for the proposed restoration strategies
- Design of layout geometrics (alignment, stationing, ditch sections, culvert design).
- Identification of potential utility conflicts.
- Detailed site evaluations (beyond simply identifying potentially suitable land).
- Erosion and Sedimentation control design.
- Environmental permit applications or assessments.
- Field reconnaissance/inspections.
- Field location of existing BMPs.

AECOM
LABOR HOUR BREAKDOWN / FEE ESTIMATE
Swan Creek Sediment Restoration Plan
April 17, 2017

Task Description	Sr WR Eng/PM	Senior Engineer	WR Engineer	Tech Edit Graphics	Total Hours	Total Labor
Rate:	*$195.52*	*$108.27*	*$99.13*	*$89.76*		
Task 1 Data Collection and Review						
Project start up/obtain data	*1*	*2*	*4*			
Review data	*1*	*2*	*6*			
Compile GIS data	*1*	*4*	*8*			
Identification of Sources	*2*	*4*	*12*			
Subtotal - Task 1	5	12	30	0	47	$5,250.74
Task 2 Determination of Baseline Loads and Target Loads						
Baseline Model Development (BayFAST)	*2*	*8*	*40*			
Target Loads Model Development (BayFAST)	*2*	*8*	*40*			
Subtotal - Task 2	4	16	80	0	100	$10,444.80
Task 3 Determination of Restoration Strategies						
Identification of Restoration Strategies	*4*	*8*	*24*			
Conduct Desktop Analysis to Identify Additional Projects		*4*	*12*			
Develop Planning Level Implementation Costs	*4*	*10*	*16*			
Develop Proposed Conditions Model (BayFAST)	*2*	*8*	*20*			
Develop Priority Ranking to Identify High Priority Restoration Str	*4*	*4*	*20*			
Subtotal - Task 3	14	34	92	0	140	$15,538.42
Task 4 Develop Bynum Run Sediment Restoration Plan						
Develop Draft Plan	*10*	*24*	*60*	*8*		
Address comments and Submit Final Restoration Plan	*2*	*10*	*20*	*4*		
Subtotal - Task 4	12	34	80	12	138	$15,034.94
Meetings and Project Management						
Kickoff Meeting and Weekly Update Calls	*8*	*12*	*12*			
Meetings at 50% and 75% completion of project/minutes	*8*	*12*	*12*			
Subtotal - Task 5	16	24	24	0	64	$8,105.92
Total Hours	51	120	306	12	489	$54,375

Total Labor Costs:	**$54,375**
Direct Costs	**$582**
TOTAL Amount	***$54,957***

AECOM
DIRECT COSTS
Swan Creek Sediment Restoration Plan

Direct Costs

Item Description	Amount	Unit	Unit Cost	Total Cost
Travel/Mileage	340	Mile	$0.535	$182
Phone, postage, photos, graphics printing	1	LS	$200.00	$200
Prints	100	Sheet	$1.00	$100
misc	100	LS	$1.00	$100

Total Direct Costs: ***$582***

Watershed Restoration Monitoring

Foster Branch

Year 2 Monitoring Results

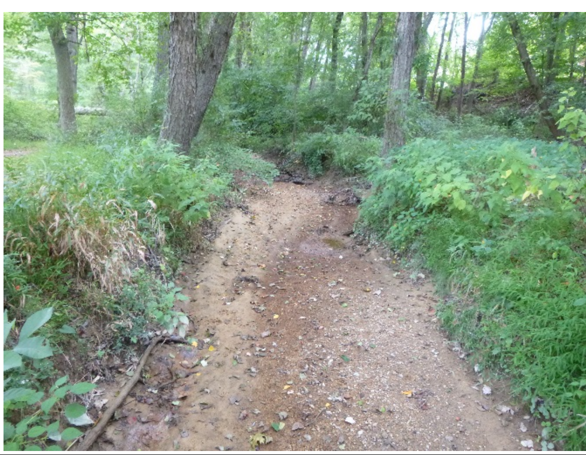
July | 2017

Prepared For

Harford County
Watershed Protection and Restoration
Department of Public Works
212 South Bond Street, 1st Floor
Bel Air, Maryland 21014

Prepared By

KCI Technologies, Inc.
936 Ridgebrook Road
Sparks, MD 21152



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TABLES

FIGURES

Background and Objectives

Harford County Department of Public Works (DPW) commissioned a watershed action plan for the Foster Branch watershed. The Foster Branch Small Watershed Action Plan (BayLand 2013) was completed in January of 2013. The plan outlines restoration projects and storm-water retrofits throughout this approximately 1,400 acre watershed. In anticipation of the permit conditions which may be placed on these restoration projects by Maryland Department of the Environment (MDE) and the U.S. Army Corps of Engineers (USACE), a monitoring plan was developed for the Foster Branch watershed. KCI Technologies, Inc. (KCI) developed the *Foster Branch Monitoring Plan* (Harford County 2016) with sites located generally upstream and downstream of proposed or constructed restoration projects.

KCI Technologies, Inc. completed the second year of chemical, physical, and biological stream sampling in spring of 2017 at the five stream sites described in the plan. This technical memorandum describes the methods and results of the first and second years of sampling conducted at the Foster Branch sites.

The primary goal of this effort is to characterize baseline stream conditions (biological, physical habitat, and *in situ* chemical) prior to additional restoration project/BMP implementation. A secondary goal is to conduct monitoring in Foster Branch that can be used to document ecological uplift and habitat improvement as projects are completed within this watershed.

1 Methods

The monitoring effort includes chemical (*in situ* water quality), physical (habitat assessment), and biological (benthic macroinvertebrate, fish, herpetofauna, freshwater mussels, and crayfish) assessments conducted at each of the selected sites. The sampling methods used are consistent with Maryland Department of Natural Resources' (DNR) Maryland Biological Stream Survey (MBSS). The methods have been developed locally and are calibrated specifically to Maryland's ecophysiographic regions and stream types.

1.1 Sampling Sites

Five sampling sites were selected within the Foster Branch watershed (Figure 1) to characterize baseline stream conditions and to assess the effect of planned restoration on the ecological health of the watershed. A brief description of sites follows, for more detailed information about each site see the *Foster Branch Monitoring Plan* (Harford County 2016).

1.1.1 Fost-1

Site Fost-1 is located close to the head-of-tide near the downstream most point in the Foster Branch watershed. This site is co-located with the USGS stream gage on Foster Branch (01585075). A stream restoration was previously completed by Harford County at this location and Fost-1 is located wholly within the restored reach. The land use upstream of Fost-1 is mostly urban (65.7%) with most of the remaining portion in forest (31.3%). This site will integrate the effects of all future restoration projects in the watershed.

1.1.2 Fost-2

Fost-2 is located on east branch of Foster Branch a short distance upstream of Trimble Rd and the confluence with the west branch. This site is located within a future planned stream restoration project. This site is the most urban of the Foster Branch sites, with 77.4% of the upstream watershed in urban and 22.1% in forest categories. This site will measure ecological response to all restoration projects on the east branch as they are implemented.

1.1.3 Fost-3

The site Fost-3 is located on the west branch of Foster Branch in a similar relative position as Fost-2, a short distance upstream of Trimble Rd and the confluence with the east branch. The west branch is the larger of the two branches of Foster Branch. This site is located a short distance downstream of both a planned stream restoration project and a planned sediment removal project. This site will integrate and assess the ecological benefit of all implemented restoration projects in the west branch.

1.1.4 Fost-4

This site is located on an unnamed tributary to the west branch, primarily draining forested (65.5%) land. This site has the smallest amount of urbanization (19.7% urban, approximately 2% impervious)) in its upstream drainage. Two large stream restoration projects are planned for the headwaters of this unnamed tributary. This site will measure ecological lift possibly attributable to stream restoration in a minimally developed subwatershed.

1.1.5 Fost-5

This site is located on an unnamed tributary to the west branch, primarily draining urban (55.2%) land. This site is much more urban than Fost-4, with approximately 29% of the upstream area in impervious land cover. This site is downstream of two planned stream restoration projects and one new stormwater BMP. This site will assess the ecological benefit of planned restoration in a heavily urbanized subwatershed.

1.2 Water Quality Sampling

Water quality conditions were measured *in situ* during the summer sampling visits at all Foster Branch sites. Currently the MBSS does not measure *in situ* water quality at sites, but did so in the past. *In situ* water quality methods used were consistent with those in DNR, 2010. Field measured parameters include temperature, dissolved oxygen, pH, specific conductance, and turbidity. Measurements at each site were made at the upstream end of the 75-meter long site. *In situ* measurements were made before any sampling activities started to avoid sampling water disturbed by other activities. Most *in situ* parameters (i.e., temperature, pH, specific conductivity, and dissolved oxygen) were measured using a multiparameter sonde (YSI Professional Plus), while turbidity was measured with a Hach 2100 Turbidimeter. Water quality meters are regularly inspected and maintained and were calibrated immediately prior to sampling to ensure proper usage and accuracy of the readings.

1.3 Physical Habitat Assessment

Each stream site was characterized based on visual observations of physical characteristics and various habitat parameters. The Maryland Biological Stream Survey's (MBSS) Physical Habitat Index (PHI; Paul et al., 2002) was used to assess the physical habitat at the site.

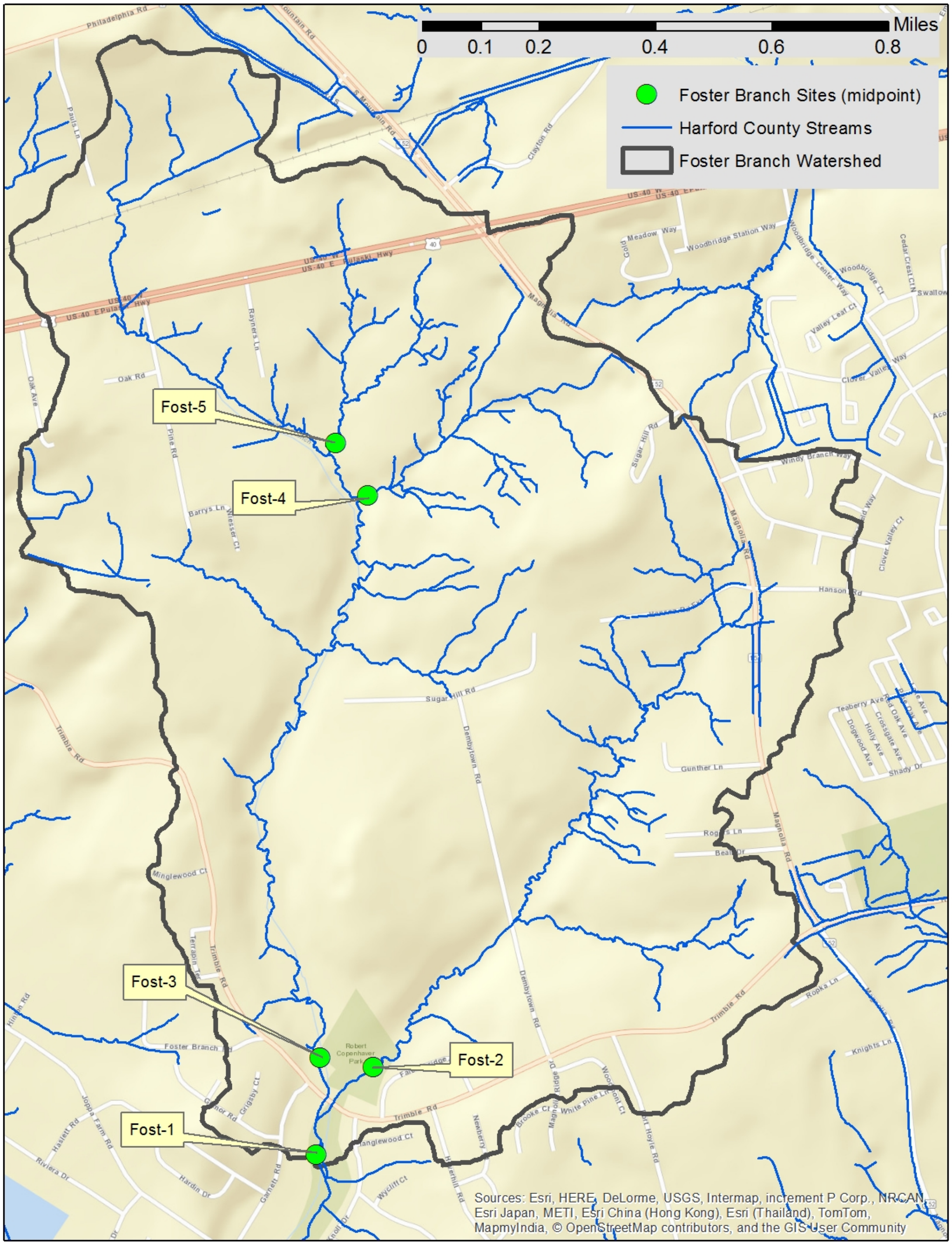

Figure 1 – Location of Sampling Sites

To reduce individual sampler bias, assessments were completed as a team with discussion and agreement of the scoring for each parameter. In addition to the visual habitat assessments, photographs were taken from three locations within each sampling reach (downstream end, midpoint, and upstream end) facing in the upstream and downstream direction, for a total of six (6) photographs per site.

The PHI incorporates the results of a series of habitat parameters selected for Coastal Plain, Piedmont and Highlands regions. While all parameters are rated during the field assessment, the Coastal Plain parameters were used to develop the PHI score for these sites because the Foster Branch watershed is located in Maryland's coastal plain ecophysiographic region. In developing the PHI, MBSS identified eight parameters that have the most discriminatory power for the coastal plain streams. These parameters are used in calculating the PHI (Table 1). Several of the parameters have been found to be drainage area dependent and are scaled accordingly. The drainage area to each site was calculated in GIS using the GPS-collected location of each site, streams and 2-foot contour data from Harford County.

Table 1 – PHI Coastal Plain Parameters

Coastal Plain Stream Parameters	
Instream Habitat	Epibenthic Substrate
Bank Stability	Percent Shading
Remoteness	Number Woody Debris/Root wads

Each habitat parameter is given an assessment score ranging from 0-20, with the exception of shading (percentage 0-100%) and woody debris and root wads (total count). A prepared score and scaled score (0-100) are then calculated. The average of these scores yields the final PHI score. The final scores are then ranked according to the ranges shown in Table 2 and assigned corresponding narrative ratings, which allows for a score that can be compared to habitat assessments performed statewide.

Table 2 – PHI Score and Ratings

PHI Score	Narrative Rating
81.0 – 100.0	Minimally Degraded
66.0 – 80.9	Partially Degraded
51.0 – 65.9	Degraded
0.0 – 50.9	Severely Degraded

1.4 Benthic Macroinvertebrate Sampling

Benthic macroinvertebrate collection strictly followed MBSS procedures (Stranko et al., 2015). Sampling occurred during the Spring Index Period (March 1 – April 30), samples were collected from all five Foster Branch sites on March 9, 2017. The monitoring sites consist of a 75-meter reach and benthic macroinvertebrate sampling is conducted once per year. The sampling methods utilize semi-quantitative field collections of the benthic macroinvertebrate community. The multi-habitat D-frame net approach is used to sample a range of the most productive habitat types present within the reach. Best available habitats include riffles, stable woody debris, root wads, root mats, leaf packs, aquatic macrophytes, and undercut banks. In this sampling approach, a total of twenty jabs (each approximately one square foot) are distributed proportionally among all best available habitats within the stream site and combined into a single composite sample and preserved in 95 percent ethanol. The composite sample contains material collected from approximately 20 square feet of habitat.

MBSS specifies that a minimum of 5% (1 in 20) of sites are selected for a duplicate sample (Stranko et al., 2015). Because the total number of samples in this project (5) is well below 20, Foster Branch samples were pooled with other County monitoring project samples from Plumtree Run (5) to meet the field sampling QC objective (1 in 10, or 10.0%). The randomly selected QC site for 2017 was taken at a site in the Foster Branch watershed, Fost-1.

1.4.1 Benthic Macroinvertebrate Sample Processing and Laboratory Identification

Benthic macroinvertebrate samples were processed and subsampled according to methods described in the MBSS Laboratory Methods for Benthic Macroinvertebrate Processing and Taxonomy (Boward and Friedman 2011). Subsampling was conducted to standardize the sample size and reduce variation caused by samples of different size. In this method, the sample was spread evenly across a numbered, gridded tray (100 total grids), and a grid was picked at random and picked clean of organisms. If the organism count was 100 or more, then the subsampling was complete. If the organism count was less than 100, then another grid was selected at random and picked clean of organisms. This repeated until the organism count reached 100 to 120 organisms. The 100 (plus 20 percent) organism target is used to allow for specimens that are missing parts or are not mature enough for proper identification, are terrestrial, or meiofauna. Identification of the subsampled specimens was conducted by Environmental Services and Consulting, Inc. Taxa were identified to the genus level for most organisms. Groups including Oligochaeta and Nematomorpha were identified to the family level while Nematomorpha was left at phylum. Individuals of early instars or those that were damaged were identified to the lowest possible level, which could be phylum or order, but in most cases was family. Chironomidae could be further subsampled depending on the number of individuals in the sample and the numbers in each subfamily or tribe. Most taxa were identified using a stereoscope. Temporary slide mounts viewed with a compound microscope were used to identify Oligochaeta to family and for Chironomid sorting to subfamily and tribe. Permanent slide mounts were then used for Chironomid genus level identification. Results were logged on a bench sheet and entered into a spreadsheet for analysis.

Benthic macroinvertebrate lab quality control procedures followed those used by the MBSS (Boward and Friedman 2011). Because the total number of samples in this project (5) is well below 20, Foster Branch samples were pooled with samples from Plumtree Run (5) to meet the laboratory QC objective (1 in 10, or 10.0%). The lab QC samples were selected at random from either Foster Branch or Plumtree Run samples. One (1) sample was randomly selected for QC re-identification by an independent lab.

1.4.2 Benthic Macroinvertebrate Data Analysis

Benthic macroinvertebrate data were analyzed by KCI using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The Benthic Index of Biotic Integrity (BIBI) approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. The metrics selected fall into five major groups including taxa richness, composition measures, tolerance to perturbation, trophic classification, and habit measures. Raw values from each metric were given a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled IBI score from 1.0 to 5.0, and a corresponding narrative biological condition rating was applied.

Three sets of metric calculations have been developed for Maryland streams based on broad eco-physiographic regions. These include the Coastal Plain, Piedmont and combined Highlands. The study area is located in the Coastal Plain region therefore the following metrics (Table 3) and IBI scoring (Table 4) were used for the analysis.

Table 3 – Benthic Macroinvertebrate Metric Scoring for the Coastal Plain BIBI

Metric	Score		
	5	3	1
Total Number of Taxa	≥ 22	14 – 21	< 14
Number of EPT Taxa	≥ 5	2 – 4	< 2
Number of Ephemeroptera Taxa	≥ 2	1 – 1	< 1
% Intolerant to Urban	≥ 28	10 - 27	< 10
% Ephemeroptera	≥ 11	0.8 – 10.9	< 0.8
Number of Scraper Taxa	≥ 2	1 - 1	< 1
% Climbers	≥ 8	0.9 – 7.9	< 0.9

*Adjusted for catchment size

Table 4 – BIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

1.5 Fish Sampling

The fish community at each of the five Foster Branch sites was sampled during the Summer Index Period, June 1 through September 30, according to methods described in *Maryland Biological Stream Survey: Round Four Field Sampling Manual* (Stranko et al., 2015). In general, the approach uses two-pass electrofishing of the entire 75-meter study reach. Block nets were placed at the upstream and downstream ends of the reach, as well as at tributaries or outfall channels, to obstruct fish movement into or out of the study reach. Two passes were completed along the reach to ensure the segment was adequately sampled. The time in seconds for each pass was recorded and the level of effort for each pass was similar. Captured fish were identified to species and enumerated following MBSS protocols (Stranko et al., 2015). A total fish biomass for each electrofishing pass was measured. Unusual anomalies such as fin erosion, tumors etc., were recorded. Photographic vouchers were taken in lieu of voucher specimens.

1.5.1 Fish Data Analysis

Fish data for Foster Branch sites were analyzed using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (DNR, 2005). The IBI approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. Raw values from each metric were assigned a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled FIBI score, ranging from 1.0 to 5.0, and a corresponding narrative rating of 'Good', 'Fair', 'Poor' or 'Very Poor' was applied, again in accordance with standard practice.

Four sets of FIBI metric calculations have been developed for Maryland streams based on DNR, 2005. These include the Coastal Plain, Eastern Piedmont, and warmwater and coldwater Highlands. Foster Branch is located in the Coastal Plain region, therefore, the following metrics listed in Table 5 were used for the FIBI scoring (Table 6) and analysis.

Table 5 – Fish Metric Scoring for the Coastal Plain FIBI

Metric	Score		
	5	3	1
Abundance per square meter	≥ 0.72	0.45 – 0.71	< 0.45
Number of Benthic species *	≥ 0.22	0.01 – 0.21	0
% Tolerant	≤ 68	69 – 97	> 97
% Generalist, Omnivores, Invertivores	≤ 92	93 - 99	100
% Round-bodied Suckers	≥ 2	1	0
% Abundance of Dominant Taxa	≤ 40	41 - 69	< > 69

*Adjusted for catchment size

Table 6 – FIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

1.6 Herpetofauna Survey

Herpetofauna (i.e., reptiles and amphibians) were surveyed at each of the five Foster Branch sites using methods following MBSS protocols (Stranko et al., 2015); 1) incidental collection, and 2) a search within all suitable stream salamander habitats within the 75-meter site. All collected individuals were identified to species level and released. Photographic vouchers were collected if a specimen could not be positively identified in the field.

Herpetofauna data collection occurs primarily to assist MBSS with supplementing their inventory of biodiversity in Maryland's streams. Currently, MBSS has not developed any indexes of biotic integrity for herpetofauna, and therefore, they were not used to evaluate the biological integrity of sampling sites throughout this study. Rather, the data are provided to help document existing conditions.

1.7 Freshwater Mussel Survey

A survey of freshwater mussels was conducted at each site using MBSS protocols (Stranko et al., 2015). A search for freshwater mussels was conducted at each site. Any live individuals encountered were identified, photographed, and then returned back to the stream as closely as possible to where they were collected. Any dead shells were retained as voucher specimens.

1.8 Crayfish Survey

Crayfish were surveyed for at each site using MBSS protocols (Stranko et al., 2015). All crayfish observed while electrofishing were captured and retained until the end of each electrofishing pass. Captured crayfish were identified to species and counted before release back into the stream outside of the 75-meter sampling reach. Any crayfish encountered outside of the electrofishing effort were identified and noted on the datasheet as an incidental observation. Any crayfish burrows observed in and around the sampling site were excavated and an attempt made to capture the burrowing crayfish.

1.9 Invasive Plant Survey

A survey of invasive plants was performed at each site during the Summer Index Period following MBSS protocols (Stranko et al., 2015). The common name and relative abundance of invasive plants (i.e., present or extensive) within view of the study reach and within the 5-meter riparian vegetative zone parallel the stream channel were recorded.

Invasive plant data collection occurs to assist MBSS with supplementing their inventory of biodiversity. The data are provided to help document existing conditions at each site.

1.10 Quality Assurance and Quality Control

All work was conducted with thorough quality assurance and quality control. Biological assessment methods have been designed to be consistent and comparable with the methods used by MBSS (Stranko et al., 2015). Field crews receive yearly training in MBSS protocols and certification by DNR to perform benthic macroinvertebrate and fish sampling procedures. The Certified Fish Sampling Field Crew Leader and Fish Taxonomist for this project was Andy Becker. All field forms are checked and signed by the Crew Leader before leaving the site. Digital data entry is also checked for accuracy. Field equipment are checked regularly and calibrated as necessary prior to use. Calculation of metric scores and IBIs are completed using KCI's controlled and verified spreadsheet and each site undergoes a documented quality control check.

2 Results and Discussion

Biological monitoring and water quality sampling were conducted to assess the conditions in the Foster Branch watershed. Presented below are the summary results for each monitoring component.

2.1 Water Quality

Water quality measurements were collected during the Summer Index Period sampling visit at each of the five Foster Branch sites. Table 7 presents the results of the *in situ* water quality measurements for Year 1 (summer 2015) and Year 2 (summer 2016).

Table 7 – In Situ Water Quality Measurement Results

Site	Season	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (Units)	Specific Conductance (µS/cm)	Turbidity (NTU)
Fost-1	Summer 2015	19.0	8.46	6.96	269.0	3.88
Fost-1	Summer 2016	22.0	8.86	6.92	325.6	20.9
Fost-2	Summer 2015	17.2	2.13	6.57	224.2	6.47
Fost-2	Summer 2016	20.0	1.24	6.39	282.3	10.4
Fost-3	Summer 2015	19.4	8.36	6.86	260.4	4.63
Fost-3	Summer 2015	18.2	7.91	6.90	247.5	4.82
Fost-4	Summer 2015	18.0	6.35	6.83	112.4	10.1
Fost-4	Summer 2015	n/a	n/a	n/a	n/a	n/a
Fost-5	Summer 2015	17.1	8.76	7.48	617.0	1.44
Fost-5	Summer 2015	n/a	n/a	n/a	n/a	n/a

Shaded cells indicate values exceeding either water quality criteria or published values

MDE has established acceptable water quality standards for each designated Stream Use Classification, which are listed in the *Code of Maryland Regulations (COMAR) 26.08.02.03-.03 - Water Quality*. Foster Branch is covered in *COMAR* in Sub-Basin 02-13-08: Gunpowder River Area as Use I waters. Specific designated uses for Use I streams include growth and propagation of fish and aquatic life, water supply for industrial and agricultural use, water contact sports, fishing, and leisure activities involving direct water contact.

The acceptable criteria for Use I waters are as follows:

- pH - 6.5 to 8.5
- DO - may not be less than 5 mg/l at any time
- Turbidity - maximum of 150 Nephelometric Turbidity Units (NTU's) and maximum monthly average of 50 NTU
- Temperature - maximum of 90°F (32°C) or ambient temperature of the surface water, whichever is greater

In situ water quality measurements for temperature, pH, and turbidity for 2015 and 2016 were within COMAR standards for Use I streams. Measurement of dissolved oxygen at Fost-2 was 2.13 mg/L during the 2015 visit and 1.24 mg/L during the 2016 visit, below the Use I instantaneous criterion of 5.0 mg/L. The cause of the low dissolved oxygen measurement was likely due to the flow at this site being greatly reduced, the site was reduced to standing pools at the time of sampling during both 2015 and 2016. With no flow to bring oxygenated water into the site, biological processes had likely reduced the dissolved oxygen available in what little water existed in the site. Although MDE does not have a water quality standard for specific conductivity, Morgan et al. (2007) have reported critical values for specific conductance in Maryland streams, above which there is a potential for detrimental effects on the stream biological communities. For the benthic macroinvertebrate community that critical value is 247 µS/cm, and for the fish community it is 171 µS/cm. Four of the five Foster Branch stream sites had specific conductivity value exceeding the threshold for fish community impairment, and exceedances were measured at these four sites during all *in situ* sampling events. Four of the five also had values exceeding the benthic macroinvertebrate threshold, with Fost-1 and Fost-3 exceeding during both years, Fost-2 exceeding only during 2016, and Fost-5 exceeding during its only sampling event in 2015. Only Fost-4 had specific conductivity below both thresholds. Conductivity levels in this watershed are likely influenced by runoff from impervious surfaces (i.e., roads, sidewalks, parking lots, roof tops). Increased stream inorganic ion concentrations (i.e., conductivity) in urban systems typically results from paved surface de-icing, accumulations in storm-water management facilities (Casey et al., 2013), runoff over impervious surfaces, passage through pipes, and exposure to other infrastructure (Cushman, 2006). While elevated conductivity may not directly affect stream biota, its constituents (e.g., chloride, metals, and nutrients) may be present at levels that can cause biological impairment.

2.2 Physical Habitat Assessment

The summary results of the PHI habitat assessments are presented in Table 8. All Foster Branch sites have compromised physical habitat, with PHI ratings of either 'Degraded' or 'Severely Degraded'. Fost-4 and Fost-5 had the best habitat scores of the five sites, reflecting their location in a minimally-disturbed tract of forest. The relatively low habitat scores are likely due to urbanization effects on streams. Complete physical habitat data for each site are included in Appendix A.

Table 8 – RBP and PHI Habitat Assessment Results

Site	Season	PHI Score	PHI Narrative Rating
Fost-1	Summer 2015	46.4	Severely Degraded
Fost-1	Summer 2016	55.9	Degraded
Fost-2	Summer 2015	34.3	Severely Degraded
Fost-2	Summer 2016	38.9	Severely Degraded
Fost-3	Summer 2015	44.7	Severely Degraded
Fost-3	Summer 2016	55.7	Degraded
Fost-4	Summer 2015	60.1	Degraded
Fost-5	Summer 2015	64.4	Degraded

2.3 Benthic Macroinvertebrate Community

The results of benthic macroinvertebrate community assessments for Year 2 are presented in Table 9. Complete benthic macroinvertebrate data for each site are included in Appendix B.

Table 9 – Benthic Index of Biotic Integrity (BIBI) Summary Data – Year 2

Metric	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5	Fost-1QC
Metric Values						
Total Number of Taxa	24	17	22	26	24	17
Number of EPT Taxa	4	1	0	4	2	3
Number of Ephemeroptera Taxa	0	0	0	0	0	0
% Intolerant to Urban	1.35	2.44	2.24	15.63	0.58	0.00
% Ephemeroptera	0.00	0.00	0.00	0.00	0.00	0.00
Number of Scraper Taxa	3	4	5	1	3	2
% Climbers	4.05	3.66	24.63	7.03	3.47	3.82
Metric Scores						
Total Number of Taxa	5	3	5	5	5	3
Number of EPT Taxa	3	1	1	3	3	3
Number of Ephemeroptera Taxa	1	1	1	1	1	1
% Intolerant to Urban	1	1	1	3	1	1
% Ephemeroptera	1	1	1	1	1	1
Number of Scraper Taxa	5	5	5	3	5	5
% Climbers	3	3	5	3	3	3
BIBI Score	***2.71***	***2.14***	***2.71***	***2.71***	***2.71***	***2.43***
Narrative Rating	***Poor***	***Poor***	***Poor***	***Poor***	***Poor***	***Poor***

Foster Branch sites had BIBI ratings all in the 'Poor' category. Fost-1, Fost-3, Fost-4, and Fost-5 each scored 2.71, While Fost-2 scored the lowest at 2.14. These consistently low BIBI scores are possibly due to poor habitat and water quality. During Year 1, all sites except for Fost-4 had measured specific conductivity values greater than the published impairment threshold for benthic macroinvertebrates. Conversely, Fost-4 had the lowest measured specific conductivity and the highest proportion of organisms intolerant to urbanization. That pattern held true for Year 2 as well for the three sites that had summer *in situ* water quality collected.

The QC sample from Fost-1 scored similarly to the non-QC sample, in the 'Poor' category. The QC sample had fewer taxa, driving the BIBI lower than the non-QC sample. This is most likely due to the naturally-occurring patchy distribution of benthic macroinvertebrates.

A comparison of BIBI scores across the two years of monitoring is presented in Table 10 and Figure 2. BIBI scores in Year 2 were generally higher than in Year 1. Three sites had BIBI scores that here higher in Year 2, one site did not change between Years 1 and 2, and one site had a BIBI score that was lower in Year 2. Sites Fost-1 (+0.57), Fost-4 (+0.28), and Fost-5 (+0.85) all had higher scores in Year 2. Fost-2 scored a 2.14 for both years. Site Fost-3 (-0.29) had a lower score in Year 2. Analysis at the end of Year 3 monitoring will allow the development of relationships between BIBI score and habitat, land use, and/or water quality.

Table 10 – BIBI Scores and Narrative Rating for all Years

Site	Year	BIBI Score	Narrative Rating
Fost-1	1 (Spring 2016)	2.14	Poor
Fost-1	2 (Spring 2017)	2.71	Poor
Fost-2	1 (Spring 2016)	2.14	Poor
Fost-2	2 (Spring 2017)	2.14	Poor
Fost-3	1 (Spring 2016)	3.00	Fair
Fost-3	2 (Spring 2017)	2.71	Poor
Fost-4	1 (Spring 2016)	2.43	Poor
Fost-4	2 (Spring 2017)	2.71	Poor
Fost-5	1 (Spring 2016)	1.86	Very Poor
Fost-5	2 (Spring 2017)	2.71	Poor

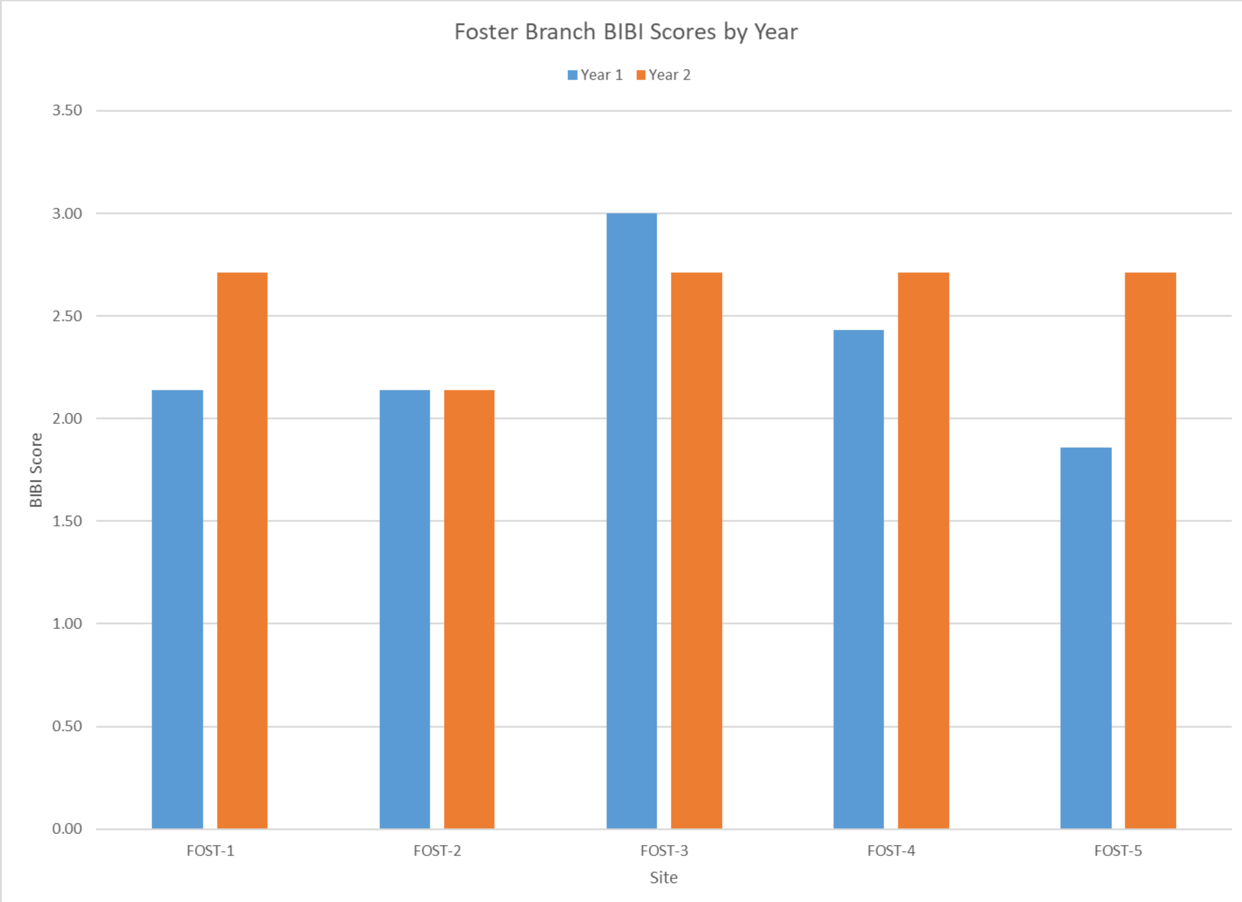

Figure 2 – BIBI Scores by Year

2.4 Fish Community

The results of the fish community assessments are presented in Table 11 and a cumulative list of species collected at each site can be found in Table 12. Complete fish community data for each site are included in Appendix C.

Table 11 – Fish Index of Biotic Integrity (FIBI) Summary Data – Year 2

Metric	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Metric Values					
Abundance per square meter	1.59	n/a	2.17	n/a	n/a
Adjusted Number of Benthic species	1.37	n/a	1.67	n/a	n/a
% Tolerant	68.56	n/a	74.84	n/a	n/a
% Generalist, Omnivores, Invertivores	89.83	n/a	96.54	n/a	n/a
% Round-bodied Suckers	4.73	n/a	0.00	n/a	n/a
% Abundance of Dominant Taxon	17.49	n/a	52.20	n/a	n/a
Metric Scores					
Abundance per square meter	5	1	5	n/a	n/a
Adjusted Number of Benthic species	5	1	5	n/a	n/a

% Tolerant	5	1	3	n/a	n/a
% Generalist, Omnivores, Invertivores	3	1	3	n/a	n/a
% Round-bodied Suckers	5	1	1	n/a	n/a
% Lithophilic Spawners	5	1	3	n/a	n/a
FIBI Score	***5.00***	***1.00***	***3.33***	***n/a***	***n/a***
Narrative Rating	***Good***	***Very Poor***	***Fair***	***n/a***	***n/a***

Table 12 – Cumulative List of Fish Species Collected at Foster Branch Sites

Common Name	Scientific Name	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Least Brook Lamprey	*Lampetra aepyptera*	X		X		
Sea Lamprey	*Petromyzon marinus*			X		
American Eel	*Anguilla rostrata*	X		X		X
Brown Bullhead	*Ameiurus nebulosus*	X				
Creek Chubsucker	*Erimyzon oblongus*	X				
Northern Hogsucker	*Hypentelium nigricans*	X				
White Sucker	*Catostomus commersonii*	X		X		
Eastern Silvery Minnow	*Hybognathus regius*	X				
Rosyside Dace	*Clinostomus funduloides*	X		X		X
Satinfin Shiner	*Cyprinella analostana*	X		X		
Spottail Shiner	*Notropis hudsonius*	X				
Creek Chub	*Semotilus atromaculatus*	X	X	X	X	X
Blacknose Dace	*Rhinichthys atratulus*	X	X	X	X	X
Banded Killifish	*Fundulus diaphanus*	X		X		
Mummichog	*Fundulus heteroclitus*	X		X		X
Tessellated Darter	*Etheostoma olmstedi*	X		X		
Largemouth Bass	*Micropterus salmoides*	X		X		
Bluespotted Sunfish	*Enneacanthus gloriosus*	X				
Lepomis sp.	*Lepomis sp.*	X				
Redbreast Sunfish	*Lepomis auritus*	X		X		
Bluegill	*Lepomis machrochirus*	X				
Pumpkinseed	*Lepomis gibbosus*	X		X		

The Foster Branch sites had FIBI ratings ranging across the entire spectrum from ‘Very Poor’ to ‘Good’.

Site Fost-1 had the highest possible FIBI score, 5.00 which rated ‘Good’. Twenty species of fish were collected during Year 2 at Fost-1, the highest diversity of the five sites across both years. The diversity of fish collected at this site helped to drive the FIBI score into the ‘Good’ category.

Fost-2 had a FIBI that scored the lowest of the five sites, 1.00 or ‘Very Poor’, which is the lowest possible score. No fish were collected at this site during Year 2 sampling. This site was reduced to standing pools during both the summer of 2015 and 2016, reducing greatly the space and resources available to stream fish. Water quality may also be poor at this site, Fost-2 had elevated specific conductivity value when measured during the summer sampling visit during both years. The ecological condition at this site is likely affected both by a lack space and habitat, and by poor water quality.

Site Fost-3 scored a 3.33 which was in the ‘Fair’ category. This site had twelve species collected during sampling. While less diverse than Fost-1, the metrics scored well because of the smaller drainage area.

Neither Fost-4 nor Fost-5 were sampled during Year 2. These sites are small headwater streams which were outlined in the Foster Branch Monitoring Plan as being sampled less frequently as the rest of the Foster Branch sites.

A comparison of FIBI scores across the two years of monitoring is presented in Table 13 and Figure 3. Sites Fost-4 and Fost-5 were only sampled during Year 1 so comparison across years is not possible for these sites. Fost-1 had a slightly higher FIBI score (+0.33) in Year 2, a 5.00 compared to a 4.67. Fost-2 scored a 1.00, the lowest possible score, for both Year 1 and Year 2. During both years of sampling at Fost-2 the site was reduced to standing pools. This lack of water and habitat space likely is the cause of the low FIBI scores at this site. Site Fost-3 had a lower FIBI score (-1.00) in Year 2 than in Year 1, a 3.33 vs a 4.33. Analysis at the end of Year 3 monitoring will allow the development of relationships between FIBI score and habitat, land use, and/or water quality.

Table 13 – FIBI Scores and Narrative Rating Across Years

Site	Year	FIBI Score	Narrative Rating
Fost-1	1 (Summer 2015)	4.67	Good
Fost-1	2 (Summer 2016)	5.00	Good
Fost-2	1 (Summer 2015)	1.00	Very Poor
Fost-2	2 (Summer 2016)	1.00	Very Poor
Fost-3	1 (Summer 2015)	4.33	Good
Fost-3	2 (Summer 2016)	3.33	Fair
Fost-4	1 (Summer 2015)	1.67	Very Poor
Fost-4	2 (Summer 2016)	n/a	n/a
Fost-5	1 (Summer 2015)	2.67	Poor
Fost-5	2 (Summer 2016)	n/a	n/a

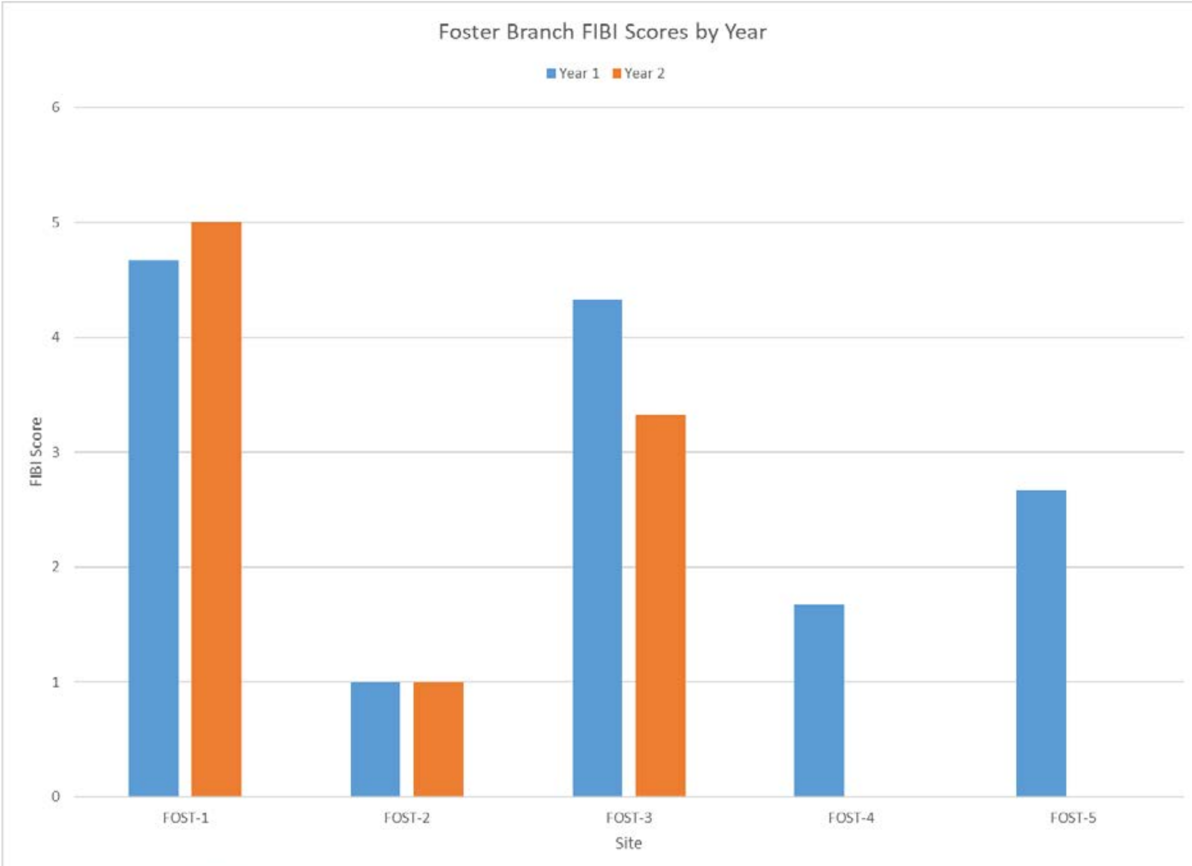

Figure 3 – FIBI Scores by Year

2.5 Herpetofauna

At least two amphibian species were collected at each of the sites (Table 14). Fost-1 has the highest diversity with five species present at the site. The most widely distributed species was Northern Green Frog, which was present at all five of the Foster Branch sites. Stream salamander species were observed at three of the five sites during the stream salamander search or incidentally during other sampling activities. Northern Two-lined Salamander was observed at Fost-2 during the summer 2015 field visit, at Fost-1 during the summer 2016 visit, and at Fost-5 during both summer 2015 and summer 2016. At Fost-1 and Fost-2 a single individual was captured during electrofishing activities, but none were observed during the targeted stream salamander search. At Fost-5 one individual was observed while electrofishing during the summer 2015 sampling event but no salamanders were encountered during the targeted stream salamander search. During summer of 2016 no electrofishing took place at Fost-5 but one individual was encountered during the stream salamander search.

Table 14 – Cumulative Herpetofauna Presence at Foster Branch Sites

Common Name	Scientific Name	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Cope's Gray Treefrog	*Hyla chrysoscelis*			X	X	
American Bullfrog	*Lithobates catesbeianus*	X				
Northern Green Frog	*Lithobates clamitans melanota*	X	X	X	X	X
Pickerel Frog	*Lithobates palustris*	X	X	X		
Northern Spring Peeper	*Pseudacris crucifer*	X				

Stream Salamanders						
Northern Two-lined Salamander	*Eurycea bislineata*	X	X			X

The low density of stream salamanders at three sites, and lack of stream salamanders at two of the five sites is likely due to a combination of habitat degradation and water quality impairment. There was very little suitable stream salamander habitat present at those sites for the field crew to search. The restoration reach (Fost-1) contained several areas of armored banks and rock structures in the stream. Those areas are not preferred habitat for stream salamanders. The non-restored sites had a dominant substrate of sand which in not a preferred habitat of stream salamanders. Stream salamanders generally prefer large cover objects over loose cobble and gravel, creating a moist microclimate and many interstices for shelter and foraging. Stream salamanders breathe through their skins and because of their highly permeable skin are particularly sensitive to water quality impairments. The high conductivity values suggest that salamanders would experience osmotic difficulties in these conditions.

2.6 Freshwater Mussels

No freshwater mussels were observed at any Foster Branch site during either year of sampling. The lack of freshwater mussels at these sites is likely due to a combination of habitat degradation and water quality impairment. Freshwater mussels are relatively sessile organisms which live partially embedded within the stream substrates. The flashy hydrology characteristic of urban streams like Foster Branch create habitat conditions unsuitable for freshwater mussels. Also, it is likely that water quality conditions in urban streams are outside the range of tolerance of these sensitive organisms.

2.7 Crayfish

No crayfish were observed at three of the five Foster Branch sites. *Orconectes limosus*, a native species, was the only crayfish species observed at these sites and was observed at Fost-1 during electrofishing in both Year 1 and Year 2 and at Fost-3 during Year 2. Crayfish burrows were observed only at Fost-4 and Fost-5, the sites located in a minimally-disturbed tract of forest. Burrows were observed at these sites during both years of sampling. These burrows most likely were dug by *Cambarus diogenes*, but no specimens were collected to confirm this. The lack of crayfish may be due to habitat degradation. Both Fost-2 and Fost-3 had evidence of recent high flows, suggesting that flashy urban hydrology may frequently disturb cover objects reducing the availability of suitable crayfish habitat at those sites. Water quality conditions may also be impacting crayfish, but currently the water quality requirements for crayfish in Maryland are poorly understood.

2.8 Invasive Plant Species

Invasive plant species were present at all of the Foster Branch sites. Table 15 presents all invasive species found at each monitoring site cumulatively for all sampling visits. Fost-5 has the most invasive plant species with six, and Fost-4 had the least with two. Japanese stiltgrass was the most widely distributed invasive plant, found at all five sites. Oriental bittersweet and Multiflora rose were the next most widely distributed species, each being found at four sites.

Table 15 – Cumulative Invasive Plant Species Presence at Foster Branch Sites

Common Name	Scientific Name	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Garlic mustard	*Alliaria petiolata*		X			
Japanese barberry	*Berberis thunbergii*					X

Oriental bittersweet	*Celastrus orbiculatus*		X	X	X	X
Autumn olive	*Elaeagnus umbellata*			X		
Chinese Lespedeza	*Lespedeza cuneata*	X				
Japanese honeysuckle	*Lonicera japonica*		X			X
Japanese stiltgrass	*Microstegium vimineum*	X	X	X	X	X
Mile-a-minute	*Persicaria perfoilata*					X
Phragmites	*Phragmites sp.*	X				
Multiflora rose	*Rosa multiflora*	X	X	X		X

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Plumtree Run

Year 2 Monitoring Results

July | 2017

Prepared For

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Background and Objectives

Harford County Department of Public Works (DPW) commissioned a watershed action plan for the Plumtree Run watershed. The Plumtree Run Small Watershed Action Plan (BayLand 2011) was completed in June of 2011. The plan outlines restoration projects and storm-water retrofits throughout this approximately 1,650 acre watershed. In anticipation of the permit conditions which may be placed on these restoration projects by Maryland Department of the Environment (MDE) and the U.S. Army Corps of Engineers (USACE), a monitoring plan was developed for the Plumtree watershed.

KCI Technologies, Inc. completed the second year of chemical, physical, and biological stream sampling in spring of 2017 at the five stream sites described in the plan. This technical memorandum describes the methods and results of the first and second years of sampling conducted at those sites in the Plumtree Run watershed.

The primary goal of this effort is to characterize baseline stream conditions (biological, physical habitat, and *in situ* chemical) prior to additional restoration project/BMP implementation. A secondary goal is to conduct monitoring in Plumtree Run that can be used to document ecological uplift and habitat improvement as projects are completed within this watershed.

1 Methods

The monitoring effort includes chemical (*in situ* water quality), physical (habitat assessment), and biological (benthic macroinvertebrate, fish, herpetofauna, freshwater mussels, and crayfish) assessments conducted at each of the selected sites. The sampling methods used are consistent with Maryland Department of Natural Resources' (DNR) Maryland Biological Stream Survey (MBSS). The methods have been developed locally and are calibrated specifically to Maryland's ecophysiographic regions and stream types.

1.1 Sampling Sites

Five sampling sites were selected within the Plumtree Run watershed (Figure 1) to characterize baseline stream conditions and to assess the effect of planned restoration on the ecological health of the watershed. A brief description of sites follows, for more detailed information about each site see the *Plumtree Run Monitoring Plan* (Harford County 2016).

1.1.1 Plum-1

Site Plum-1 is the downstream-most site in the Plumtree Run watershed. This site is located on the mainstem of Plumtree Run in the area of the USGS gage at Plumtree Road. This site will be used to measure overall watershed response to the restoration treatments implemented within the watershed. Since this site is located so close to the USGS gage on Plumtree Run, future analysis of the relationships between biological parameters, stream flow, and water quality may be possible. The land use upstream of Plum-1 is mostly urban and suburban (87.9%) with the remaining portion in agriculture (7.2%) and forest (4.8%). This site will integrate the effects of all future restoration projects in the watershed.

1.1.2 Plum-2

Plum-2 is located on the mainstem of Plumtree Run downstream of Tollgate Road within a previously completed stream restoration reach. The catchment upstream of this site is mostly urban and suburban land (90.4%) with the remaining land classified as agriculture (5.8%) and forest (3.8%). This site will measure ecological response to all restoration projects upstream of this point as those projects are implemented. This site will also directly measure habitat and ecological lift at the previously restored reach. This site is located approximately 420 meters downstream of a MBSS site (HA-P-151-10-96) sampled in 1996.

1.1.3 Plum-3

Plum-3 is located on the mainstem of Plumtree Run downstream of the political boundary of the Town of Bel Air. The upstream catchment to this site is mostly urban (93.5%) with the remaining land classified as agriculture (6.5%). This site will assess the ecological health of Plumtree Run as it enters Harford County's jurisdiction. It will also measure ecological response to future restoration as projects are implemented within the Town of Bel Air.

1.1.4 Plum-4

This site is located on an unnamed tributary to Plumtree Run, primarily draining urban (71.3%) land. The Plumtree Run plan identified extensive stream restoration and stormwater retrofit projects upstream of the site. This site will measure ecological lift possibly attributable to the planned restoration in this urbanized part of the Plumtree Run watershed.

1.1.5 Plum-5

This site is located on an unnamed tributary to Plumtree Run, primarily draining urban (98.7%) land. This site is downstream of two planned stream restoration projects and one stormwater BMP retrofit. This site will assess the ecological benefit of planned restoration in a heavily urbanized subwatershed.

1.2 Water Quality Sampling

Water quality conditions were measured *in situ* during the summer 2015 sampling visits at all Plumtree Run sites. Currently the MBSS does not measure *in situ* water quality at sites, but did so in the past. *In situ* water quality methods used were consistent with those in DNR, 2010. Field measured parameters include temperature, dissolved oxygen, pH, specific conductance, and turbidity. Measurements at each site were made at the upstream end of the 75-meter long site. *In situ* measurements were made before any sampling activities started to avoid sampling water disturbed by other activities. Most *in situ* parameters (i.e., temperature, pH, specific conductivity, and dissolved oxygen) were measured using a multiparameter sonde (YSI Professional Plus), while turbidity was measured with a Hach 2100 Turbidimeter. Water quality meters are regularly inspected and maintained and were calibrated immediately prior to sampling to ensure proper usage and accuracy of the readings.

1.3 Physical Habitat Assessment

Each stream site was characterized based on visual observations of physical characteristics and various habitat parameters. The Maryland Biological Stream Survey's (MBSS) Physical Habitat Index (PHI; Paul et al. 2002) was used to assess the physical habitat at the site.

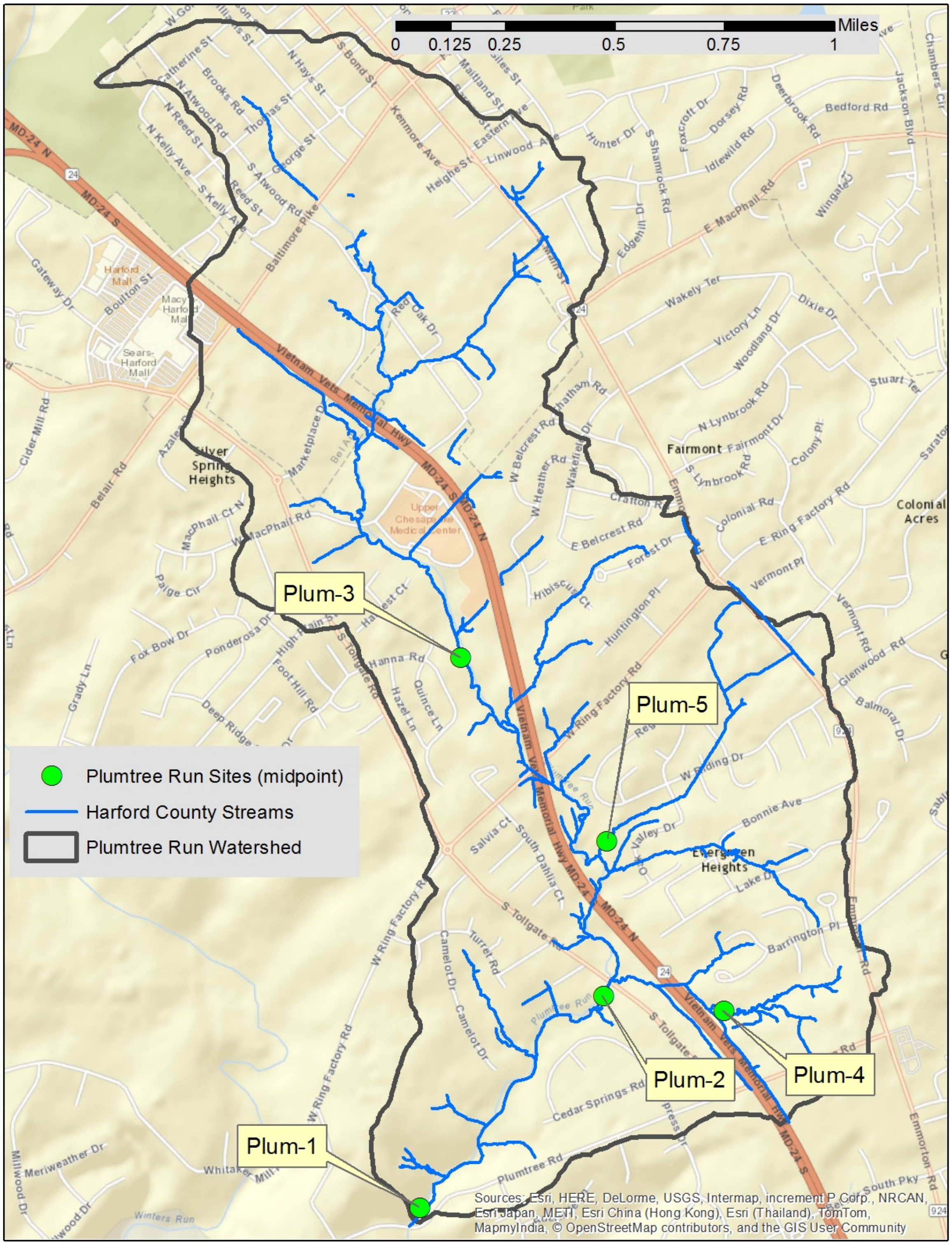

Figure 1 – Location of Sampling Sites

To reduce individual sampler bias, assessments were completed as a team with discussion and agreement of the scoring for each parameter. In addition to the visual assessments, photographs were taken from three locations within each sampling reach (downstream end, midpoint, and upstream end) facing in the upstream and downstream direction, for a total of six (6) photographs per site.

The PHI incorporates the results of a series of habitat parameters selected for Coastal Plain, Piedmont and Highlands regions. While all parameters are rated during the field assessment, the Piedmont parameters were used to develop the PHI score for these sites because the Plumtree Run watershed is located in Maryland's Piedmont ecophysiographic region. In developing the PHI, MBSS identified eight parameters that have the most discriminatory power for the Piedmont streams. These parameters are used in calculating the PHI (Table 1). Several of the parameters have been found to be drainage area dependent and are scaled accordingly. The drainage area to each site was calculated in GIS using the GPS-collected location of each site, streams and 2-foot contour data from Harford County.

Table 1 – PHI Piedmont Parameters

Piedmont Stream Parameters	
Instream Habitat	Epifaunal Substrate
Bank Stability	Percent Shading
Remoteness	Number Woody Debris/Root wads

Each habitat parameter is given an assessment score ranging from 0-20, with the exception of shading (percentage 0-100%) and woody debris and root wads (total count). A prepared score and scaled score (0-100) are then calculated. The average of these scores yields the final PHI score. The final scores are then ranked according to the ranges shown in Table 2 and assigned corresponding narrative ratings, which allows for a score that can be compared to habitat assessments performed statewide.

Table 2 – PHI Score and Ratings

PHI Score	Narrative Rating
81.0 – 100.0	Minimally Degraded
66.0 – 80.9	Partially Degraded
51.0 – 65.9	Degraded
0.0 – 50.9	Severely Degraded

1.4 Benthic Macroinvertebrate Sampling

Benthic macroinvertebrate collection strictly followed MBSS procedures (Stranko et al. 2015). Sampling occurred during the Spring Index Period (March 1 – April 30), samples were collected from all five Plumtree Run sites on April 14, 2016. The monitoring sites consist of a 75-meter reach and benthic macroinvertebrate sampling is conducted once per year. The sampling methods utilize semi-quantitative field collections of the benthic macroinvertebrate community. The multi-habitat D-frame net approach is used to sample a range of the most productive habitat types present within the reach. Best available habitats include riffles, stable woody debris, root wads, root mats, leaf packs, aquatic macrophytes, and undercut banks. In this sampling approach, a total of twenty kicks or jabs (each approximately one square foot) are distributed proportionally among all best available habitats within the stream site and combined into a single composite sample and preserved in 95 percent ethanol. The composite sample contains material collected from approximately 20 square feet of habitat.

MBSS specifies that a minimum of 5% (1 in 20) of sites are selected for a duplicate sample (Stranko et al. 2015). Because the total number of samples in this project (5) is well below 20, Plumtree Run samples were pooled with other County monitoring project samples from Foster Branch (5) to meet the field sampling QC objective (1 in 10, or 10.0%). The randomly selected QC site for 2017 was taken at a site in the Foster Branch watershed, Fost-1.

1.4.1 Benthic Macroinvertebrate Sample Processing and Laboratory Identification

Benthic macroinvertebrate samples were processed and subsampled according to methods described in the MBSS Laboratory Methods for Benthic Macroinvertebrate Processing and Taxonomy (Boward and Friedman 2011). Subsampling was conducted to standardize the sample size and reduce variation caused by samples of different size. In this method, the sample was spread evenly across a numbered, gridded tray (100 total grids), and a grid was picked at random and picked clean of organisms. If the organism count was 100 or more, then the subsampling was complete. If the organism count was less than 100, then another grid was selected at random and picked clean of organisms. This repeated until the organism count reached 100 to 120 organisms. The 100 (plus 20 percent) organism target is used to allow for specimens that are missing parts or are not mature enough for proper identification, are terrestrial, or meiofauna. Identification of the subsampled specimens was conducted by Environmental Services and Consulting, Inc. Taxa were identified to the genus level for most organisms. Groups including Oligochaeta and Nematomorpha were identified to the family level while Nematomorpha was left at phylum. Individuals of early instars or those that were damaged were identified to the lowest possible level, which could be phylum or order, but in most cases was family. Chironomidae could be further subsampled depending on the number of individuals in the sample and the numbers in each subfamily or tribe. Most taxa were identified using a stereoscope. Temporary slide mounts viewed with a compound microscope were used to identify Oligochaeta to family and for Chironomid sorting to subfamily and tribe. Permanent slide mounts were then used for Chironomid genus level identification. Results were logged on a bench sheet and entered into a spreadsheet for analysis.

Benthic macroinvertebrate lab quality control procedures followed those used by the MBSS (Boward and Friedman 2011). Because the total number of samples in this project (5) is well below 20, Plumtree Run samples were pooled with samples from Foster Branch (5) to meet the laboratory QC objective (1 in 10, or 10.0%). The lab QC samples were selected at random from either Foster Branch or Plumtree Run samples. One (1) sample was randomly selected for QC re-identification by an independent lab.

1.4.2 Benthic Macroinvertebrate Data Analysis

Benthic macroinvertebrate data were analyzed by KCI using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The Benthic Index of Biotic Integrity (BIBI) approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. The metrics selected fall into five major groups including taxa richness, composition measures, tolerance to perturbation, trophic classification, and habit measures. Raw values from each metric were given a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled IBI score from 1.0 to 5.0, and a corresponding narrative biological condition rating was applied.

Three sets of metric calculations have been developed for Maryland streams based on broad eco-physiographic regions. These include the Coastal Plain, Piedmont and combined Highlands. The study area is located in the Piedmont region therefore the following metrics (Table 3) and IBI scoring (Table 4) were used for the analysis.

Table 3 – Benthic Macroinvertebrate Metric Scoring for the Piedmont BIBI

Metric	Score		
	5	3	1
Total Number of Taxa	≥ 25	15 – 24	< 15
Number of EPT Taxa	≥ 11	5 – 10	< 5
Number of Ephemeroptera Taxa	≥ 4	2 – 3	< 2
% Intolerant to Urban	≥ 51	12 – 50	< 12
% Chironomidae	≤ 24	24 – 63	> 63
% Clingers	≥ 74	31 – 73	< 31

*Adjusted for catchment size

Table 4 – BIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

1.5 Fish Sampling

The fish community at each of the five Plumtree Run sites was sampled during the Summer Index Period, June 1 through September 30, according to methods described in *Maryland Biological Stream Survey: Round Four Field Sampling Manual* (Stranko et al. 2015). In general, the approach uses two-pass electrofishing of the entire 75-meter study reach. Block nets were placed at the upstream and downstream ends of the reach, as well as at tributaries or outfall channels, to obstruct fish movement into or out of the study reach. Two passes were completed along the reach to ensure the segment was adequately sampled. The time in seconds for each pass was recorded and the level of effort for each pass was similar. Captured fish were identified to species and enumerated following MBSS protocols (Stranko et al. 2015). A total fish biomass for each electrofishing pass was measured. Unusual anomalies such as fin erosion, tumors, etc. were recorded. Photographic vouchers were taken in lieu of voucher specimens.

1.5.1 Fish Data Analysis

Fish data for Plumtree Run sites were analyzed using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The IBI approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. Raw values from each metric were assigned a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled FIBI score, ranging from 1.0 to 5.0, and a corresponding narrative rating of 'Good', 'Fair', 'Poor' or 'Very Poor' was applied, again in accordance with standard practice.

Four sets of FIBI metric calculations have been developed for Maryland streams. These include the Coastal Plain, Eastern Piedmont, and warmwater and coldwater Highlands. Plumtree Run is located in the Eastern Piedmont region, therefore, the following metrics listed in Table 5 were used for the FIBI scoring (Table 6) and analysis.

Table 5 – Fish Metric Scoring for the Piedmont FIBI

Metric	Score		
	5	3	1
Abundance per Square Meter	≥ 1.25	0.25 – 1.24	< 0.25
Number of Benthic species *	≥ 0.26	0.09 – 0.25	< 0.09
% Tolerant	≤ 45	46 – 68	> 68
% Generalist, Omnivores, Invertivores	≤ 80	81 – 99	100
Biomass per Square Meter	≥ 8.6	4.0 – 8.5	< 4.0
% Lithophilic Spawners	≥ 61	32 – 60	< 32

*Adjusted for catchment size

Table 6 – FIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

1.6 Herpetofauna Survey

Herpetofauna (i.e., reptiles and amphibians) were surveyed at each of the five Plumtree Run sites using methods following MBSS protocols (Stranko et al. 2015); 1) incidental collection, and 2) a search within all suitable stream salamander habitats within the 75-meter site. All collected individuals were identified to species level and released. Photographic vouchers were collected if a specimen could not be positively identified in the field.

Herpetofauna data collection occurs primarily to assist MBSS with supplementing their inventory of biodiversity in Maryland's streams. Currently, MBSS has not developed any indexes of biotic integrity for herpetofauna, and therefore, they were not used to evaluate the biological integrity of sampling sites throughout this study. Rather, the data are provided to help document existing conditions.

1.7 Freshwater Mussel Survey

A survey of freshwater mussels was conducted at each site using MBSS protocols (Stranko et al. 2015). A search for freshwater mussels was conducted at each site. Any live individuals encountered were identified, photographed, and then returned back to the stream as closely as possible to where they were collected. Any dead shells were retained as voucher specimens.

1.8 Crayfish Survey

Crayfish were surveyed for at each site using MBSS protocols (Stranko et al. 2015). All crayfish observed while electrofishing were captured and retained until the end of each electrofishing pass. Captured crayfish were identified to species and counted before release back into the stream outside of the 75-meter sampling reach. Any crayfish encountered outside of the electrofishing effort were identified and noted on the datasheet as an incidental observation. Any crayfish burrows observed in and around the sampling site were excavated and an attempt made to capture the burrowing crayfish.

1.9 Invasive Plant Survey

A survey of invasive plants was performed at each site during the Summer Index Period following MBSS protocols (Stranko et al. 2015). The common name and relative abundance of invasive plants (i.e., present or extensive) within view of the study reach and within the 5-meter riparian vegetative zone parallel the stream channel were recorded.

Invasive plant data collection occurs to assist MBSS with supplementing their inventory of biodiversity. The data are provided to help document existing conditions at each site.

1.10 Quality Assurance and Quality Control

All work was conducted with thorough quality assurance and quality control. Biological assessment methods have been designed to be consistent and comparable with the methods used by MBSS (Stranko et al. 2015). Field crews receive yearly training in MBSS protocols and certification by DNR to perform benthic macroinvertebrate and fish sampling procedures. The Certified Fish Sampling Field Crew Leader and Fish Taxonomist for this project was Andy Becker. All field forms are checked and signed by the Crew Leader before leaving the site. Digital data entry is also checked for accuracy. Field equipment are checked regularly and calibrated as necessary prior to use. Calculation of metric scores and IBIs are completed using KCI's controlled and verified spreadsheet and each site undergoes a documented quality control check.

2 Results and Discussion

Biological monitoring and water quality sampling were conducted to assess the conditions in the Plumtree Run watershed. Presented below are the summary results for each monitoring component.

2.1 Water Quality

Water quality measurements were collected during the Summer Index Period sampling visit during Year 1 and Year 2 at each of the five Plumtree Run sites. Table 7 presents the results of the *in situ* water quality measurements. Complete water quality data are included in Appendix A.

Table 7 – In Situ Water Quality Measurement Results

Site	Season	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (Units)	Specific Conductance (µS/cm)	Turbidity (NTU)
Plum-1	Summer 2015	15.1	9.92	7.52	596.7	0.89
Plum-1	Summer 2016	19.4	9.01	7.41	332.2	2.23
Plum-2	Summer 2015	17.6	9.94	7.22	672.0	4.95
Plum-2	Summer 2016	21.7	7.41	6.98	357.9	3.67
Plum-3	Summer 2015	16.5	8.54	7.18	887.0	1.72
Plum-3	Summer 2016	22.6	8.36	6.92	726.0	1.30
Plum-4	Summer 2015	15.4	7.01	6.81	384.2	1.13
Plum-5	Summer 2015	17.8	7.22	7.12	433.9	1.40

MDE has established acceptable water quality standards for each designated Stream Use Classification, which are listed in the *Code of Maryland Regulations (COMAR) 26.08.02.03-.03 - Water Quality*.

Plumtree Run is covered in *COMAR* in Sub-Basin 02-13-07: Bush River Area as Use IV-P waters. Specific designated uses for Use IV-P streams include public water supply, supporting adult trout for put-and-take fishing, growth and propagation of fish and aquatic life, water supply for industrial and agricultural use, water contact sports, fishing, and leisure activities involving direct water contact.

The acceptable criteria for Use IV-P waters are as follows:

- pH - 6.5 to 8.5
- DO - may not be less than 5 mg/l at any time
- Turbidity - maximum of 150 Nephelometric Turbidity Units (NTU's) and maximum monthly average of 50 NTU
- Temperature - maximum of 75°F (23.9°C) or ambient temperature of the surface water, whichever is greater

In situ water quality measurements for temperature, dissolved oxygen, pH, and turbidity were within COMAR standards for Use IV-P streams. Although MDE does not have a water quality standard for specific conductivity, Morgan et al. (2007) have reported critical values for specific conductance in Maryland streams, above which there is a potential for detrimental effects on the stream biological communities. For the benthic macroinvertebrate community that critical value is 247 µS/cm, and for the fish community it is 171 µS/cm. Each of the five Plumtree Run stream sites had specific conductivity values far exceeding the threshold for both benthic macroinvertebrate and fish community impairments for all water quality sampling events. Conductivity levels in this watershed are likely influenced by runoff from impervious surfaces (i.e., roads, sidewalks, parking lots, roof tops). Increased stream inorganic ion concentrations (i.e., conductivity) in urban systems typically results from paved surface de-icing, accumulations in storm-water management facilities (Casey et al. 2013), runoff over impervious surfaces, passage through pipes, and exposure to other infrastructure (Cushman 2006). While elevated conductivity may not directly affect stream biota, its constituents (e.g., chloride, metals, and nutrients) may be present at levels that can cause biological impairment.

2.2 Physical Habitat Assessment

The summary results of the PHI habitat assessments for Year 1 and Year 2 are presented in Table 8. All Plumtree Run sites have compromised physical habitat, with PHI ratings of 'Degraded' for all sites in Year 1 and all sites in Year 2 except Plum-1. Plum-1 had the best habitat scores of the five sites with a 'Partially Degraded' in Year 2. The relatively low habitat scores are likely due to urbanization effects on streams. Complete physical habitat data for each site are included in Appendix B.

Table 8 – RBP and PHI Habitat Assessment Results

Site	Season	PHI Score	PHI Narrative Rating
Plum-1	Summer 2015	64.6	Degraded
Plum-1	Summer 2016	71.2	Partially Degraded
Plum-2	Summer 2015	54.0	Degraded
Plum-2	Summer 2016	58.5	Degraded
Plum-3	Summer 2015	59.0	Degraded
Plum-3	Summer 2016	64.1	Degraded
Plum-4	Summer 2015	59.5	Degraded
Plum-5	Summer 2015	54.2	Degraded

2.3 Benthic Macroinvertebrate Community

The results of Year 2 benthic macroinvertebrate community assessments are presented in Table 9. Complete benthic macroinvertebrate data for each site are included in Appendix C.

Table 9 – Benthic Index of Biotic Integrity (BIBI) Summary Data – Year 2

Metric	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
Metric Values					
Total Number of Taxa	13	14	17	15	21
Number of EPT Taxa	1	1	3	5	4
Number of Ephemeroptera Taxa	0	0	0	0	0
% Intolerant to Urban	0.55	0.00	0.00	5.52	1.33
% Chironomidae	88	80.14	81.60	52.15	62.00
% Clingers	0	13.70	19.02	10.43	8.00
Metric Scores					
Total Number of Taxa	1	1	3	3	3
Number of EPT Taxa	1	1	1	3	1
Number of Ephemeroptera Taxa	1	1	1	1	1
% Intolerant to Urban	1	1	1	1	1
% Chironomidae	1	1	1	3	3
% Clingers	1	1	1	1	1
BIBI Score	***1.00***	***1.00***	***1.33***	***2.00***	***1.67***
Narrative Rating	***Very Poor***	***Very Poor***	***Very Poor***	***Poor***	***Very Poor***

For Year 2 benthic macroinvertebrate sampling four Plumtree Run sites had BIBI ratings in the 'Very Poor' category and one site was in the 'Poor' category with a 2.00, the lowest possible score for that category.

At the Plumtree Run sites BIBI scores ranged from 1.00 to 2.00. The individual metrics scored consistently low across all sites, with no metrics scoring a '5', the highest score possible. Three metrics, Number of Ephemeroptera Taxa, Percent Intolerant to Urban, and Percent Clingers scored consistently low across all five sites with each site scoring the lowest possible '1' for these three metrics. Minor differences in the other three metrics (Total Number of Taxa, Number of EPT Taxa, and Percent Chironomidae) accounted for the variation in BIBI scores for Plum-3, Plum-4, and Plum-5. These low BIBI scores are possibly due to poor habitat and water quality. All sites had measured specific conductivity values greater than the published impairment threshold for benthic macroinvertebrates. Additional years of monitoring will allow the development of relationships between BIBI score and habitat, land use, and/or water quality.

A comparison of BIBI scores across the two years of monitoring is presented in Table 10 and Figure 2. All five of the Plumtree Run sites had BIBI scores that were lower in Year 2 than in Year 1. Site Plum-1 had the largest BIBI score difference (-1.67), scoring a 2.76 in Year 1 and a 1.00 in Year 2. Sites Plum-4 and Plum-5 had the smallest BIBI score differences (-0.33), with Plum-4 scoring a 2.33 in Year 1 and a 2.00 in Year 2

Table 10 – BIBI Scores and Narrative Rating for all Years

Site	Year	BIBI Score	Narrative Rating
Plum-1	1 (Spring 2016)	2.67	Poor
Plum-1	2 (Spring 2017)	1.00	Very Poor
Plum-2	1 (Spring 2016)	2.00	Poor
Plum-2	2 (Spring 2017)	1.00	Very Poor
Plum-3	1 (Spring 2016)	2.00	Poor
Plum-3	2 (Spring 2017)	1.33	Very Poor
Plum-4	1 (Spring 2016)	2.33	Poor
Plum-4	2 (Spring 2017)	2.00	Poor
Plum-5	1 (Spring 2016)	2.00	Poor
Plum-5	2 (Spring 2017)	1.67	Very Poor

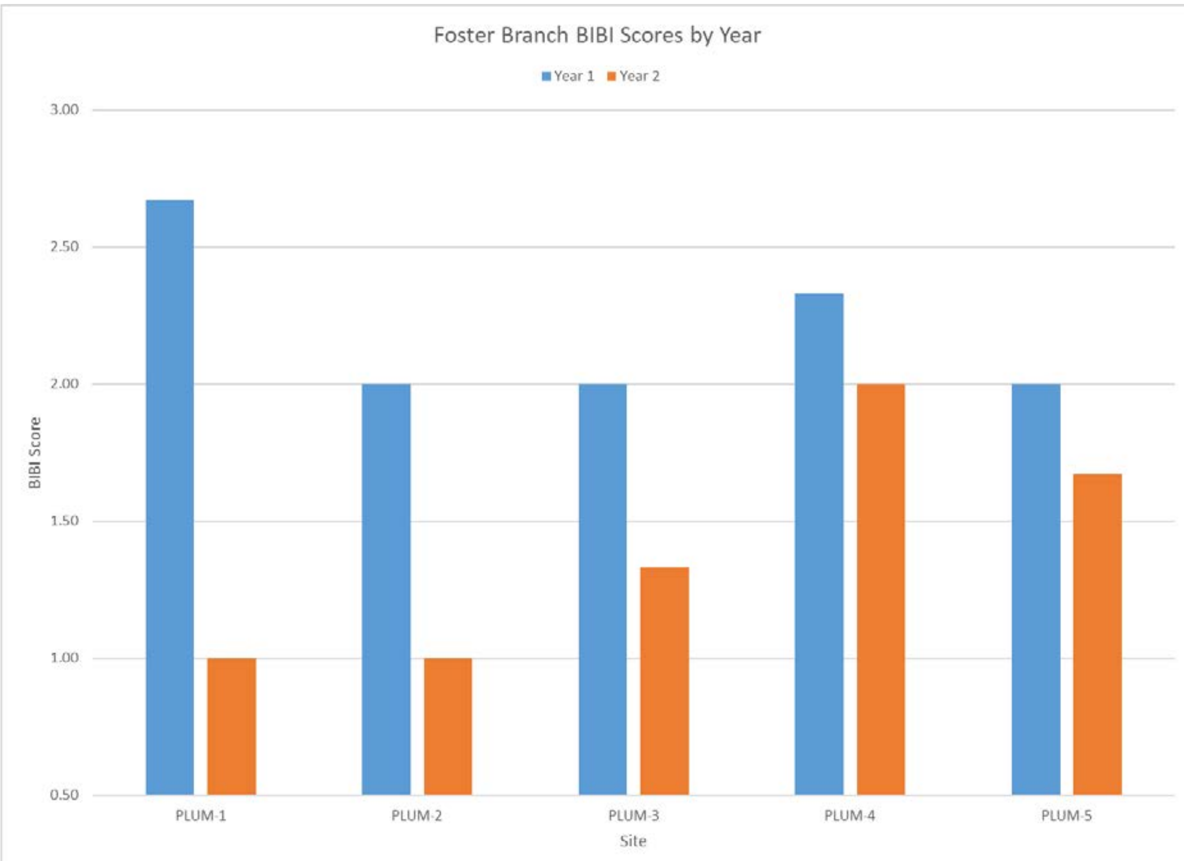

Figure 2 – BIBI Scores by Year

2.4 Fish Community

The results of the Year 2 fish community assessments are presented in Table 10 and a list of species collected at each site can be found in Table 11. Complete fish community data for each site are included in Appendix D.

Table 11 – Fish Index of Biotic Integrity (FIBI) Summary Data – Year 2

Metric	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
Metric Values					
Abundance per Square Meter	0.75	2.90	1.92	n/a	n/a
Adjusted Number of Benthic Species	0.62	0.65	0.84	n/a	n/a
% Tolerant	52.25%	64.67%	80.60%	n/a	n/a
% Generalist, Omnivores, Invertivores	69.97%	86.61%	91.40%	n/a	n/a
Biomass per Square Meter	1.82	9.38	5.60	n/a	n/a
% Lithophilic Spawners	50.75%	38.50%	49.00%	n/a	n/a
Metric Scores					
Abundance per Square Meter	3	5	5	n/a	n/a
Adjusted Number of Benthic Species	5	5	5	n/a	n/a
% Tolerant	3	3	1	n/a	n/a
% Generalist, Omnivores, Invertivores	5	3	3	n/a	n/a
Biomass per Square Meter	1	5	3	n/a	n/a
% Lithophilic Spawners	3	3	3	n/a	n/a
FIBI Score	***3.33***	***4.00***	***3.33***	***n/a***	***n/a***
Narrative Rating	***Fair***	***Good***	***Fair***	***n/a***	***n/a***

Table 12 – Cumulative List of Fish Species Collected at Plumtree Run Sites

Common Name	Scientific Name	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
White Sucker	*Catostomus commersonii*	X	X	X		
Bluntnose Minnow	*Pimephales notatus*	X	X	X		
Fathead Minnow	*Pimephales promelas*	X	X	X		
Cutlip Minnow	*Exoglossum maxillingua*		X			
Satinfin Shiner	*Cyprinella analostana*		X			
Common Shiner	*Luxilus cornutus*	X	X			
Rosyside Dace	*Clinostomus funduloides*	X	X	X		
Creek Chub	*Semotilus atromaculatus*	X	X	X	X	X
Blacknose Dace	*Rhinichthys atratulus*	X	X	X	X	X
Longnose Dace	*Rhinichthys cataractae*	X	X	X	X	X
Eastern Mosquitofish	*Gambusia holbrooki*		X			
Blue Ridge Sculpin	*Cottus caeruleomentum*	X	X	X		X
Tessellated Darter	*Etheostoma olmstedi*		X			
Redbreast Sunfish	*Lepomis auritus*		X	X		
Bluegill	*Lepomis macrochirus*			X		
Hybrid Sunfish	*Lepomis sp.*		X			

The Plumtree Run sites had FIBI ratings ranging from 'Fair' to 'Good'. Sites Plum-4 and Plum-5 were only sampled in Year 1 as per the Plumtree Run Monitoring Plan.

Site Plum-2 had the highest FIBI score, 4.00 which rated 'Good'. Sites Plum-1 and Plum-3 both scored a 3.33 rating 'Fair'. Nine species of fish have been collected at Plum-1, ten species collected at Plum-3 and 15 species collected at Plum-2 (the restored site) which had the highest diversity of the five sites.

Metrics for Adjusted Number of Benthic Species, and Percent Lithophilic Spawners were consistent between the three sites. Biomass per Square Meter varied the most between the sites, with Plum-2 scoring a '5', Plum-3 scoring a '2', and Plum-1 scoring a '1'. Minor differences in the other three metrics between sites accounted for the minor variability in FIBI scores between sites

A comparison of FIBI scores across the two years of monitoring is presented in Table 13 and Figure 3. Overall, FIBI scores at the three Plumtree Run sites monitoring in both Year 1 and Year 2 varied slightly. Plum-3 scored a 3.33 both years, Plum-1 had a slightly lower FIBI score (-0.33) in Year 2, and Plum-2 had a slightly higher FIBI score (0.33) in Year 2.

Table 13 – FIBI Scores and Narrative Rating Across Years

Site	Year	FIBI Score	Narrative Rating
Plum-1	1 (Summer 2015)	3.67	Fair
Plum-1	2 (Summer 2016)	3.33	Fair
Plum-2	1 (Summer 2015)	3.67	Fair
Plum-2	2 (Summer 2016)	4.00	Good
Plum-3	1 (Summer 2015)	3.33	Fair
Plum-3	2 (Summer 2016)	3.33	Fair
Plum-4	1 (Summer 2015)	2.67	Poor
Plum-4	2 (Summer 2016)	n/a	n/a
Plum-5	1 (Summer 2015)	2.67	Poor
Plum-5	2 (Summer 2016)	n/a	n/a

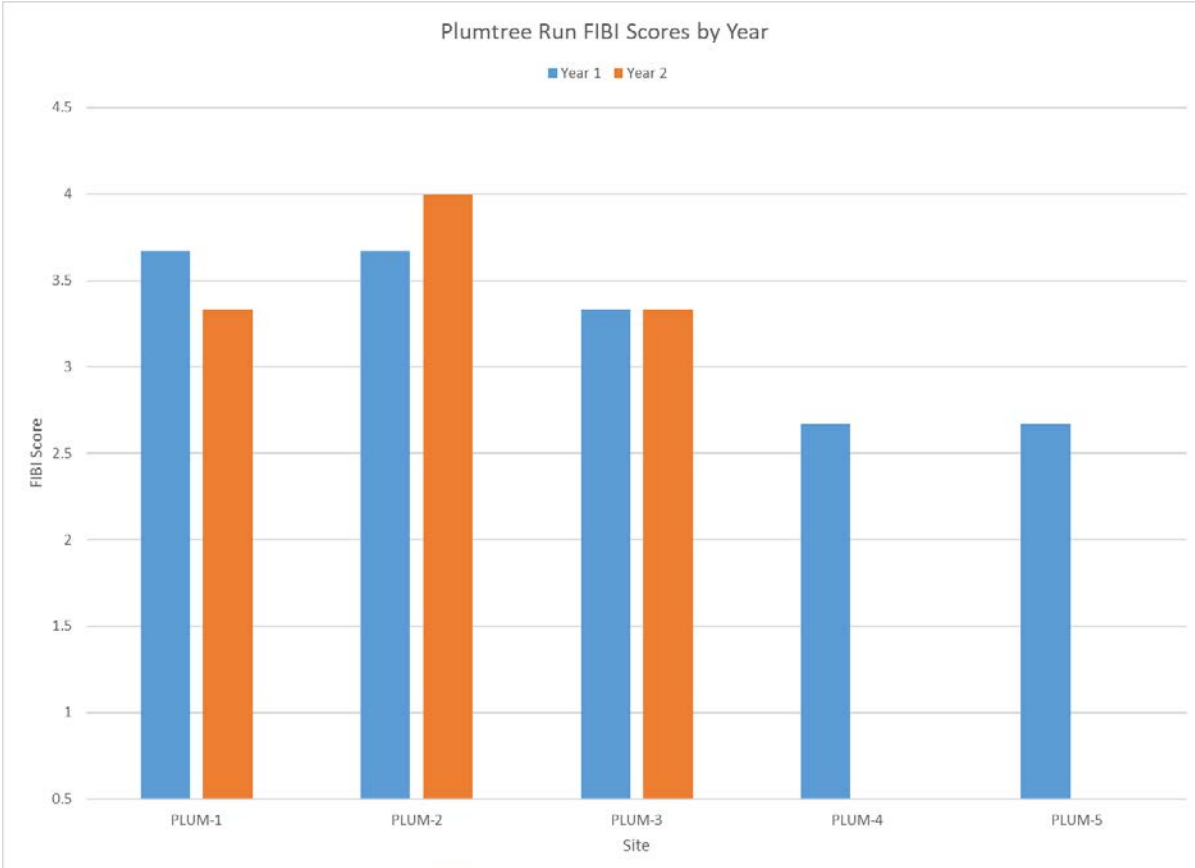

Figure 3 – FIBI Scores by Year

2.5 Herpetofauna

At least two reptile or amphibian species were collected at each of the sites (Table 12). Plum-2 had the highest diversity with four species present at the site. The most widely distributed species was Northern Two-lined Salamander, which was present at each of the five Plumtree Run sites. Numbers of stream salamander individuals were low at all sites where they were observed; one or two Northern Two-lined Salamander individuals were observed at most sites, Plum-5 had the greatest stream salamander abundance with four Northern Two-lined Salamanders and one Northern Dusky observed during summer of 2015.

Table 14 – Cumulative Herpetofauna Presence at Plumtree Run Sites

Common Name	Scientific Name	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
American Toad	*Anaxyrus americanus*	X		X		
Northern Green Frog	*Lithobates clamitans melanota*	X	X	X	X	
Northern Spring Peeper	*Pseudacris crucifer*		X			
Northern Watersnake	*Nerodia sipedon sipedon*		X			
Stream Salamanders						
Northern Dusky Salamander	*Desmognathus fuscus*					X
Northern Two-lined Salamander	*Eurycea bislineata*	X	X	X	X	X

The low density of stream salamanders at all sites is likely due to a combination of habitat degradation and water quality impairment. There was very little suitable stream salamander habitat present at Plum-2 during both years for the field crew to search. Stream salamanders generally prefer large cover objects over loose cobble and gravel, creating a moist microclimate and many interstices for shelter and foraging. The restoration reach (Plum-2) contained several areas of armored banks and rock structures in the stream. Water quality may be influencing the distribution of stream salamanders in the Plumtree Run watershed. Measured specific conductivity was high at all five sites, ranging from 332 to 887 µS/cm. Stream salamanders breathe through their skins, and because of their highly permeable skin are particularly sensitive to water quality impairments. The high conductivity values suggest that salamanders would experience osmotic difficulties in these conditions.

2.6 Freshwater Mussels

No freshwater mussels were observed at any Plumtree Run site in Year 1 nor Year 2. The lack of freshwater mussels at these sites is likely due to a combination of habitat degradation and water quality impairment. Freshwater mussels are relatively sessile organisms which live partially embedded within the stream substrates. The flashy hydrology characteristic of urban streams like Plumtree Run create habitat conditions unsuitable for freshwater mussels. Also, it is likely that water quality conditions in urban streams are outside the range of tolerance of these sensitive organisms.

2.7 Crayfish

Crayfish were observed at each of the five Plumtree Run sites. *Orconectes virilis*, a non-native species, was the only crayfish species observed at these sites. At Plum-1, Plum-2, and Plum-3 *O. virilis* was observed during electrofishing in both Year 1 and Year 2 sampling efforts. Crayfish burrows were not observed at any of the Plumtree Run sites. The lack of native crayfish is most likely due to competition with non-native crayfish. In the Patapsco River watershed, *Orconectes virilis* has displaced the native *Orconectes limosus* from the entire watershed (Kilian et al. 2010). It is likely that a similar species displacement has occurred in the Winters Run watershed. Water quality conditions may also be impacting crayfish, but currently the water quality requirements for crayfish in Maryland are poorly understood.

2.8 Invasive Plant Species

Invasive plant species were present at each of the five Plumtree Run sites. Table 13 presents all invasive species found at each monitoring site across all sampling visits. Plum-2 has the most invasive plant species with eleven, and Plum-4 had the least with four. Japanese stiltgrass and Mulitflora rose were the most widely distributed invasive plant, each found at all five sites.

Table 15 – Cumulative Invasive Plant Species Presence at Plumtree Run Sites

Common Name	Scientific Name	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
Garlic Mustard	*Allaria petiolata*		X			
Common ragweed	*Ambrosia artemisiifolia*		X			
Japanese barberry	*Berberis thunbergii*	X			X	
Oriental bittersweet	*Celastrus orbiculatus*	X		X		X
Fireweed	*Chamerion angustifolium*			X		
Autumn Clematis	*Clematis terniflora*		X			
Ground ivy	*Glechoma hederacea*		X			

English ivy	*Hedera helix*	X	X			
Chinese Lespedeza	*Lespedeza cuneata*		X			
Japanese honeysuckle	*Lonicera japonica*			X		X
Japanese stiltgrass	*Microstegium vimineum*	X	X	X	X	X
Mile-a-minute	*Persicaria perfoilata*		X			X
Multiflora rose	*Rosa multiflora*	X	X	X	X	X
Wineberry	*Rubus phoenicolasius*		X		X	
Vinca vine	*Vinca sp.*		X			

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